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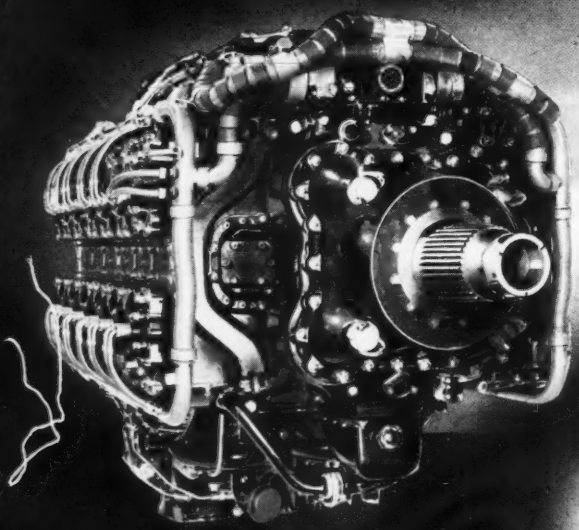

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THE SOCIETY'S PRIZES

The Society offers a number of valuable prizes, most of them annually. Full particulars of the conditions attaching to the awards of these prizes may be obtained on application

Society's Gold Medal

This is the highest honour which the Society can confer for work of an outstanding or fundamental nature in aeronautics.

British Gold Medal for Aeronautics

The British Gold Medal for Aeronautics is awarded for an achievement leading to advancement in aeronautical science.

Simms Gold Medal

The Simms Gold Medal is awarded annually for the best paper read in any year before the Society on any science allied to aeronautics, e.g., meteorology, wireless telegraphy, instruments.

The George Taylor (of Australia) Gold Medal

The Taylor Gold Medal is awarded annually, at the discretion of the Council, for the most valuable paper submitted or read during the previous session.

Wakefield Gold Medal

The Wakefield Gold Medal is awarded annually to the designer of any invention or apparatus tending towards safety in flying, and is open to members or non-members.

Society's Silver Medal

The Society's Silver Medal is awarded, at the discretion of the Council, for some advance in aeronautical design.

British Silver Medal for Aeronautics

The British Silver Medal for Aeronautics is awarded for an achievement leading to advancement in aeronautical science.

Society's Bronze Medal

The Society's Bronze Medal is awarded, at the discretion of the Council, under the same conditions as those for the Silver Medal, but for some less important advance in aeronautical design.

Wilbur Wright Memorial Premium

The Wilbur Wright Memorial Lecture is held annually, a premium of fifty pounds being awarded to the lecturer invited by the Council to deliver the lecture. The lecture is usually given alternately by an American and an Englishman, and is the most important aeronautical lecture of the year. It is delivered whenever possible, on the last Thursday in May of each year.

British Empire Lecture

The Council of the Royal Aeronautical Society have completed the arrangements for the founding of a British Empire Lecture.

The lecture, on any aeronautical subject approved by the Council, will be delivered annually in September in London, by a lecturer, chosen in alternate years from the British Dominions and Colonies and Great Britain.

The Council, by founding this British

Empire Lecture, are anxious to encourage new ideas and new points of view from all parts of the British Empire, and to make the Lecture second only in importance to the Wilbur Wright Memorial Lecture.

The British Empire Lecture will have a premium of £50 attached to it, and in the case of lecturers coming from the Dominions and Colonies an allowance up to £100 will be paid towards the Lecturer's expenses.

It is proposed to hold the first lecture in September, 1945, and suggestions for lecturers should be received by May 31st, 1945, at the latest.

R.38 Memorial Prize

The R.38 Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in the science of aeronautics, preference being given to papers which relate to airships. The prize is twenty-five guineas.

The Herbert Akroyd Stuart Lectures

Under the will of the late Mr. Herbert Akroyd Stuart a sum of £700 is held in trust by the Society for the offer of a prize every two years, for the best paper or lecture read or given before the Society dealing with the Origin and Development of Heavy-oil Aero Engines. The prize is open to members and non-members.

Edward Busk Memorial Prize

The Edward Busk Memorial Prize is offered annually for the best paper received by the Society on some subject of a technical nature in connection with aeroplanes (including seaplanes). Its value is twenty guineas.

Pilcher Memorial Prize

The Pilcher Memorial Prize is offered annually, at the discretion of the Council, for the best paper by a Student on heavier-than-air craft or any analogous subject. Its value is five guineas.

Usborne Prize

The Usborne Prize is offered annually, at the discretion of the Council, for the best paper by a Student on some subject in connection with Aero Engines. Its value is five guineas.

Major Baden-Powell Memorial Prize

The Major Baden-Powell Memorial Prize is awarded in May and December of each year to the student who is considered the best student by the examiners in the Society's Association Fellowship examinations. Its value is three guineas.

Elliott Memorial Prize

The Elliott Memorial Prize is awarded twice yearly to the apprentice at Halton who has the highest percentage of marks in the passing-out examination. Its value is $2\frac{1}{2}$ guineas for each award.

R. P. Alston Memorial Prize

The R. P. Alston Memorial Prize is awarded to any Graduate or Student of the Society for work done leading to improvement in the safety of aircraft, and particularly for improvement in stability and control. Its value is approximately £5.

Branch Prize

The Council offer an annual prize of twenty guineas for the best paper read before the Branches during the previous lecture Session. The prize is open to any member of the Society or of any Branch.

Journal Premium Awards

The Council has set aside an annual sum of £250 to be given as premium awards to authors of papers published in the Journal.

AN APPRECIATION

The Council of the Royal Aeronautical Society wish to thank those Companies who, by their generous co-operation, have done so much to help in the production of the Journal in its new form.

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The Journal of The Royal Aeronautical Society was founded in 1897 in succession to the Annual Reports. For the opinions expressed in Papers that are signed or initialled the authors alone are responsible. None of the papers or paragraphs must be taken as expressing the opinion of the Council of The Royal Aeronautical Society unless such is definitely stated to be the case. **The Journal is published monthly at the Offices of the Society, 4, Hamilton Place, Piccadilly, London, W.1.** Subscriptions per annum, £4 10 0 post free; Single Numbers 7/0 or 7/9 post free. All communications for publication in the Journal, or on general matters affecting the Society should be addressed to—The Secretary, J. Laurence Pritchard, 4, Hamilton Place, W.1. The Society's Bankers are Messrs. Coutts and Co. All communications respecting Advertisement matters should be addressed to—The Advertisement Manager, Journal of The Royal Aeronautical Society, 4, Hamilton Place, W.1.
Telephone: Grosvenor 3515-3516-3517. Telegraphic Address: Didaskolas, Audley, London.

MAY NOTICES 1945

JOURNAL PREMIUM AWARDS

The Council have set aside an annual sum of £250 for the award of premiums for papers published in the *Journal* and the Council hope that members will contribute papers on their own special subjects.

Contents of the Journal

Many members who have so generously foregone their copies of the JOURNAL while paper is heavily rationed only receive the Monthly Notices. Many have asked that the contents of the JOURNAL should be given in these Notices. In future the current papers will be noted. The following are the papers published up to date in 1945:—

JANUARY

History of the Aeronautical Journal, by Captain J. Laurence Pritchard, Hon. F.R.Ae.S., pp. 8-13.

Rationalisation of Aluminium Alloy Specifications, by A. E. Russell, B.Sc., F.R.Ae.S., pp. 14-20.

Theorems for the Synthesis of Simply-Stiff Frameworks, by H. Roxbee-Cox, Ph.D., B.Sc., D.I.C., F.R.Ae.S., pp. 21-25.

Design Factors of Civil Aircraft Affecting the Operating Costs, by R. K. Pierson, C.B.E., B.Sc., A.M.Inst.C.E., F.R.Ae.S., pp. 26-32.

FEBRUARY

Notes on Power-Operated Controls for Large Aircraft, by A. Gouge, B.Sc., F.R.Ae.S., pp. 51-54.

Civil Aviation Discussion, pp. 55-98.

MARCH

On the Solution of the Numerical Simultaneous Equations Arising in the Analysis of Redundant Structures, by F. J. Turton, B.Sc., A.R.C.S., pp. 104-111.

Graphics of World Aviation, by A. J. Dilloway, pp. 112-140.

Civil Aviation Discussion, pp. 141-155.

APRIL

The Importance of Power Unit Development, by Air Commodore F. R. Banks, O.B.E., F.R.Ae.S., pp. 161-213.

Note on Aircraft Structural Failures and Factors for Safety, by Squadron-Leader J. G. M. Pardoe, pp. 214-217.

Value of Weight-Saving in Air Liners, by Major F. M. Green, pp. 218-220.

MAY

Aeroplane Wheels and Brakes, by J. Wright, A.F.R.Ae.S., pp. 225-250.

Civil Aviation Discussion, p. 268.

Wilbur Wright Memorial Lecture

The 33rd Wilbur Wright Memorial Lecture will be read at 6.30 p.m. on Thursday, May 31st, 1945, by Mr. T. P. Wright, Hon.F.R.Ae.S., on "Aviation's Place in Civilisation." The lecture will be held at the Institution of Mechanical Engineers, Storey's Gate, St. James's, S.W.1 (by permission of the Council of the Institution). Light refreshments will be served before the meeting. Visitors will be admitted by ticket, obtainable through Members only.

Branch Lectures

LUTON BRANCH

Wednesday, 23rd May—Hydraulics for Aircraft, by Mr. R. H. Bound, F.R.Ae.S.

Wednesday, 6th June—Aircraft Timber, by Mr. F. T. Bozier.

PORTSMOUTH BRANCH

Friday, 18th May—Short Papers by Members.

Graduates' and Students' Section

Wednesday, 6th June—Informal Impromptu Discussion. The meeting will be held at 7.30 p.m., at 4, Hamilton Place, W.1.

Membership Committee

A Membership Committee has been appointed by the Council with the following terms of reference:—

"To assess what changes in the rules, if any, should be made to attract potential members without lowering the status of the technical grades of the Society.

"To make recommendations to the Council of the Royal Aeronautical Society."

The Committee consists of the following members:—

Dr. H. C. Watts (Fellow).
Major B. W. Shilson (Fellow) (Chairman).
Mr. R. K. Pierson (Fellow).
Captain J. G. Hopcraft (Associate Fellow).
Mr. E. J. Archbold (Graduate).
Mr. A. G. Elliott (Fellow).
Mr. A. C. Clinton (Fellow).

The object of the Committee is to explore the ground to find out in what ways the activities of the Society can be increased for the benefit of its members, and to investigate if any changes in the present Rules are necessary to enable those who are not already members to become so.

The Committee will appreciate letters from any members putting forward for consideration suggestions for increasing the membership or activities of the Society, or any other suggestions which may occur to them.

Election of Members

The following members were recently elected:—

Associate Fellows

William Shepherd Allen, Charles Bower, Arthur James Cobley, Harry George Philip Ellery, Peter Farr (from Graduate), William Pitcairn Kemp, Alfred Lipfriend (from Graduate), John Henry Littlewood, Roy Hume Long (from Graduate), Robert Mathieson, Robert Edward Martin Braben Milne, Andre Albert Perriches, Peter Person (from Graduate), Peter George Stannard (from Student), Robert William Symmons, Robert Reid Walls, Daniel Edgar Cuthbert Vaughan-Mallinson (from Associate).

Associates

John Clifford Yorke Baker, Stephen Blumenthal (from Graduate), Arthur Breeze-Carr, Thomas Vernon Broughton, Eric Charles Brunning, Peter Egbert Cadbury, Stephen John Chaffey, Herbert John Cohen, S. A. Shiraz-ud-Dean, Bramwell Ernest Downs, Robert Haworth, Richard Cameron Hogarth, Arthur Sidney Hill, Harischandra Kashinath Karve, Joseph Leather, Wilfred Lees, Donald Lewis-Jones, James Lyon McLennan (from Student), Robert McRobert, Marcus Dyce Manton, Stanley Edward Matthews, John McGhee, Richard Nicholson, John Maskill Noble, Patrick Joseph O'Leary, Waldo Barker Price-Owen, Thomas William Scarbrough, Reginald Edmund Toilerfield, Frederick Walter Ware, Cyril George Jones, William Devon Doble (from Student).

Graduates

Eric Aubrey, Raymond Edwin Cooper (from Student), Martin Cox, Geoffrey Townsend Dobson (from Student), Jack Ford, Peter Ian Warren Harvey (from Student), Thomas Allan Harvie, Cyril Francis Holloway, Anthony Brian Davies Leigh (from Student), Harry Ogden, Dennis Shoesmith, Eric William Stansbury, John Raymond Stevens (from Student), Raymond Wilks (from Student), Allenby William Rogers.

Students

Jesse Acum, Walter Ashwell, Thomas Elliott Burnup, George Norman Coulthard, Alan Donkin, Peter George Gillham, Paul Rous Green, Norman Herbert, Richard Alan Hobbs, Gordon Stephen Frederick Holman, William Bruce Johnstone, Thomas Michael Kelly, Francis George Lapworth, George Geoffrey Legg, Geoffrey Ernest Morley, John Michael Parks, Jean Frederic Steer, John Herbert Stephens, Kenneth Charles Thomas, Francis E. Thornycroft, David Frederick Henry Edward Trew, David Cherry Watson, Richard Mellor Willcock, Neville Henry Wood, Philip Murray Franz, John Francis Henry Jagoe.

Companions

Francis Daniel Jooste, Cornelius Hendrik van Vuuren, Laurence William Stevens Wilson.

Acknowledgments

The Council acknowledge with grateful thanks the gift of Journals from Mr. J. G. Navarro, Associate Fellow, and from Mr. L. R. Morphew, Associate.

Additions to the Library

Pamphlets in italics with location reference following in brackets. Books marked * or ** may not be taken out on loan.

A.a.312.—Aerodynamics of the Airplane. Clark B. Millikan. John Wiley, N.Y. (or Chapman & Hall, London). 1941. 15/-.

B.b.22.—Notes on Helicopter Design Theory. Alexander A. Nikolsky. Princeton University Press, 1945.

BB.f.55-58.—Sperry Gyroscope Company Booklets:—

Pub. 15-35: Gyro-Horizons; Pub. 15-36, Directional Gyros.

Pub. 15-37: Attitude Gyro; Pub. 15-38, Gyrosyn Compass. 1944.

*D.a.A.35.—*The Aircraft Industry Prepares for the Future. (Report to War Contracts Sub-Committee, U.S. Senate.) Aeronautical Chamber of Commerce of America, Inc.*, 1944. (Y.37/6.)

D.a.B.88, 89.—*Parliamentary Debates: House of Commons Official Report (Hansard). Vol.* 409, *No.* 49 (15.3.45), *and No.* 51 (20.3.45). *H.M.S.O., 6d. each.* (Y.20.ii.)

D.b.228.—*Commercial Air Transport. Reprint from Ayrshire Post, Ltd., Feb.*, 1945. (PD.1/31.)

D.b.229.—*Air Power Can Be Peace Power. G. W. Vaughan. Air Industries and Transport Association of Canada.* 1944. (PD.1/30.)

D.b.230.—The Geography of World Air Transport. J. Parker van Zandt. Brookings Institution, Washington, 1944. $1.00. (In England, 5/-.)

D.b.231.—Wings After War. S. Paul Johnston. Duell, Sloan & Pearce. 1944. $2.

EE.a.118.—Instruction Book: Ranger SGV-770C-1. Ranger Aircraft Engines, 1942.

K.c.19.—*Space Flight: The Problem of Propellants. Dr. A. M. J. Janser. "Chemical Products," Jan./Feb.*, 1945. (Y.14.b.5.)

L.d.104.—Air Navigation. Erwin F. Freundlich. Oliver & Boyd, Ltd., 1945. 7/6.

L.d.105.—Spherical Trigonometry for Navigators. Charles Williams. Sir Isaac Pitman, 1945. 5/-.

L.d.106.—Astronomical Air Navigation (2nd Ed.). Sq.-Ldr. R. Hadingham. Technical Press, Ltd., 1945. 12/-.

L.k.46.—Medical Aspects of Aviation (Speed and Acceleration). Capt. Ernst Jokl. Sir Isaac Pitman, 1943. 10/6.

M.b.52.—Radio Communication (Vol. II). J. H. Reyner. Sir Isaac Pitman, 1944. 7/6.

N.c.14.—Chemistry and the Aeroplane. Vernon J. Clancey. Thos. Nelson & Sons, 1942. 5/-.

**P.c.43-46.—Patents on Gas Turbine Plants (Abridgments). U.S.A. (1925-42); German (1925-42); Swiss (1925-42); German (1943). U.S. Navy Dept., Research and Standards Section, Bureau of Ships. 1943-44.

*Q.a.153.—Aeronautics in Alaska (Bibliography). Arthur G. Renstrom. U.S. Library of Congress, 1944.

**Q.a.154.—Technical Literature of Gas Turbine Plants (1930 to date), exclusive of Patents. U.S. Navy Dept., Research and Standards Section, Bureau of Ships. 1942.

R.f.98.—Horizons Unlimited. S. Paul Johnston. Duell, Sloan & Pearce, 1941. $3.75.

S.a.143.—*Camouflage*, 1914-1918 *Aircraft. O. G. Thetford. Harborough Publishing Co.*, 1943. 3/6. (PS.1/27.)

S.e.81.—Atlantic Bridge. Ministry of Information. H.M.S.O., 1945. 9d.

S.e.82.—R.A.F., Middle East. Ministry of Information. H.M.S.O., 1945. 1/9.

S.e.83.—Last Flight from Singapore. A. G. Donahue. Macmillan & Co., 1944. 8/6.

*X.c.M.25.—Lanz Aviation Dictionary in Nine Languages. John E. Lanz. P. D. & Ione Perkins, Pasadena (Calif.), 1944. $6.50. (In England, 40/-.)

J. LAURENCE PRITCHARD,
Secretary.

AEROPLANE WHEELS AND BRAKES*

by

J. Wright, A.F.R.Ae.S.

J. Wright is the General Manager of the Dunlop Rim and Wheel Co. Ltd. From 1925 he has been responsible for the design and development of Dunlop wheels for aircraft, and from 1940 for the production of wheels, brakes, gun-firing gear and other aircraft components. Mr. Wright has taken out over 40 patents on wheels, brakes, pumps, gun mechanisms and controls.

A MEETING of the Royal Aeronautical Society was held in the Lecture Hall of the Institution of Mechanical Engineers, Storey's Gate, St. James Park, Westminster, London, S.W.1, on Thursday, February 15th, 1945, at which a paper entitled "Aeroplane Wheels and Brakes" was presented by Mr. J. Wright, A.F.R.Ae.S. In the Chair, the President, Sir A. H. Roy Fedden.

The CHAIRMAN: Mr. Wright was a man of proven attainments and general all-round ability in that most important sphere of aeronautical engineering which determined the beginning and end of every flight, and on which the safety of passengers and crew so largely depended. Without wheels, no conventional type of aeroplane could leave the ground; and without brakes, most modern forms of aeroplane would be a menace.

Mr. Wright was General Manager of the Dunlop Wheel and Rim Company; the major portion of his professional career had been concerned with the design and development of wheels and brakes. Since 1925 he had been responsible for the design and development of all his Company's products.

Undoubtedly we had learned a great deal about aeroplane wheels and brakes during the war; but we had to learn a vast deal more before our civil aircraft were entirely satisfactory and safe, especially the larger types of machines which were visualised.

Introduction

IT is a platitude to comment that the aircraft designer spends much of his time and energy in a constant endeavour to reduce the weight of the complete aeroplane structure. The temptation to seize on the wheel as a component which should be reduced to the absolute minimum in both size and weight is great, since its actual life is small and it in no way contributes to the strength or the performance of the aeroplane when in flight.

The close attention given to the aeroplane wheel in recent years has already resulted in a considerable advance in this direction.

The Armstrong - Whitworth "Argosy" (approx. 20,000 lbs. all-up weight), produced some 15 years ago, was fitted with pneumatic tyres of the same outside diameter as are used to-day for some of our largest aeroplanes weighing upwards of 70,000 lbs.

During the earlier stages of the development of the aeroplane with its fixed undercarriage, comparatively low landing speed and high aerodynamic drag, it was possible

*Paper received January 29th, 1945.

to produce a fairly light wheel without brakes which effected a reasonable compromise.

With the modern aeroplane, with its high landing speed, low drag and retractable undercarriage, it becomes increasingly difficult to provide a wheel which will:—

(a) Be of the smallest overall dimensions. It is found that the designer of the aeroplane is obliged to consult the wheel and tyre manufacturer at a very early stage in the design of a new type, as the construction and size of the wing and/or fuselage may well depend on the size of the cavity into which the wheel is retracted.

(b) Spread the load to be carried over a sufficiently large area to avoid destruction or rapid wear of the landing surface of the aerodrome.

(c) Possess brakes sufficiently powerful and of capacity not only to arrest the aeroplane on landing, but to manœuvre on the ground during taxying.

This problem of providing a small and light wheel is made more difficult by the introduction of still heavier aeroplanes. For example, the weight of the tyres, wheels and brakes of an aeroplane weighing 10,000 lbs. is approximately $1\frac{1}{2}$ per cent. W, whereas the same figure for an aeroplane weighing 250,000 lbs. is 3 per cent. W (assuming that a conventional two-wheeled undercarriage is used).

Alternatives

It is, therefore, natural to enquire what are the possible alternatives to the wheel and pneumatic tyre which are so commonly used on all forms of land transport.

There is possibly a case for the bogey which could be dropped after " take-off," particularly where maximum performance in flight is desired. This may well be the solution for a number of military specifications. It is, however, suggested that for normal military and civil duties it is essential that the aeroplane should be "self-sufficient," and it is unlikely that the operator would accept such a complicated and elaborate procedure which this arrangement would undoubtedly entail.

Similarly, " skids " may be satisfactory for particular requirements, e.g., gliders, but would not be accepted for more general applications.

If the wheel is, therefore, accepted as a part of the aeroplane, what are the alternatives to the pneumatic tyre?

(a) The solid metal wheel. Little consideration shows that except for the lightest types of aircraft, the bearing pressure between the solid metal wheel and the ground is excessive, and it is extremely unlikely that any aerodrome surface would stand up to these concentrated loads. Again, practical experience proves the pneumatic tyre has most desirable directional properties which are absent with the solid metal wheel, even though this may be provided with an internal springing arrangement. Moreover, the solid metal wheel is not light—the pneumatic tyre is lighter—there being some truth in the statement that " It is the air that carries the load."

Fig. 1 shows a comparison of the contact areas of a pneumatic and a solid rubber tyred wheel of approximately the same overall dimensions.

In order to avoid exceeding the dimensions and weight of the pneumatic equivalent tyre, it is necessary to use a higher contact pressure. It is, however, unlikely that the civil engineers responsible for aerodrome construction would be prepared to accept contact pressures greatly in excess of 120 lbs./sq. in. This is the maximum pressure given in a recent paper by Mr. Shaw MacLaren before the Institute of Civil Engineers.

For the heavier loaded wheels it may be found, on closer examination, that the contact pressure for the solid rubber tyre is of the order of 300-500 lbs./sq. in.

An inherent disadvantage of the solid rubber tyre is its tendency to " run hot."

This results in premature failure, and precludes its use for main landing wheels which may be called on to run a considerable distance under load, during both the take-off and landing.

The solid rubber tyre may, however, be used to advantage in place of the pneumatic

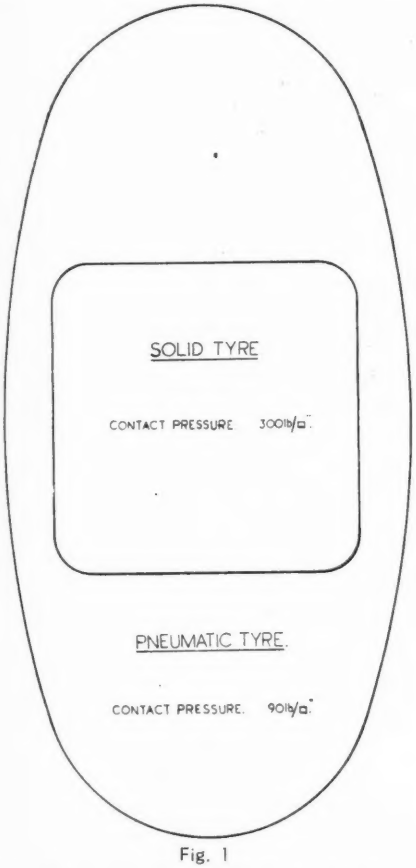

Fig. 1

tyre for some of the smaller tail wheels, where there is a tendency to increase the loading, calling for pneumatic tyre pressures of 100-150 lbs./sq. in.

Due to the limits imposed by the small dimensions it is difficult to provide a satisfactory pneumatic tyre, whereas the solid tyre may be capable of carrying the load without setting up excessive internal heat, by reason of the fact that the tail is only under load at speed for a very short period of time.

For larger sizes, however, it is my opinion that it is not possible to produce a solid rubber tyre to compare favourably with the pneumatic tyre. The overall dimensions and weight of the solid are always likely to exceed the same figures for the pneumatic equipment.

The Dowty caterpillar track has recently received considerable attention, particularly for the larger sizes of projected aeroplanes, where its small frontal area compares favourably with the conventional single pneumatic tyre.

The track is in an advanced experimental stage, and practical results will soon be available. It is the writer's opinion that it will be heavy, and that difficulty will be experienced with the small solid rubber tyred bogey wheels and the rubber track, partilarly when used on concrete runways, where the loading is concentrated immediately under the rollers, and is not evenly spread over the full area of the track in contact with the ground.

Dimensions of the Pneumatic Tyred Wheel

Whilst I am of the opinion that it is extremely unlikely that an efficient substitute for the pneumatic tyre will be found, it is encouraging to note that it should be possible to reduce substantially the size and weight of existing wheels and tyres. We have been most severely handicapped by the necessity of providing wheels which will enable the aeroplane to operate from a variety of landing surfaces, ranging from reinforced concrete to grass, sand and other types of soft terrain. The size of the tyre has been determined by the contact pressure which the landing surface will withstand without " bogging " the aeroplane.

With the almost complete absence of runways, the inflation pressure of aeroplane tyres was limited in the period immediately prior to 1939 to 35 lbs./sq. in. With this pressure

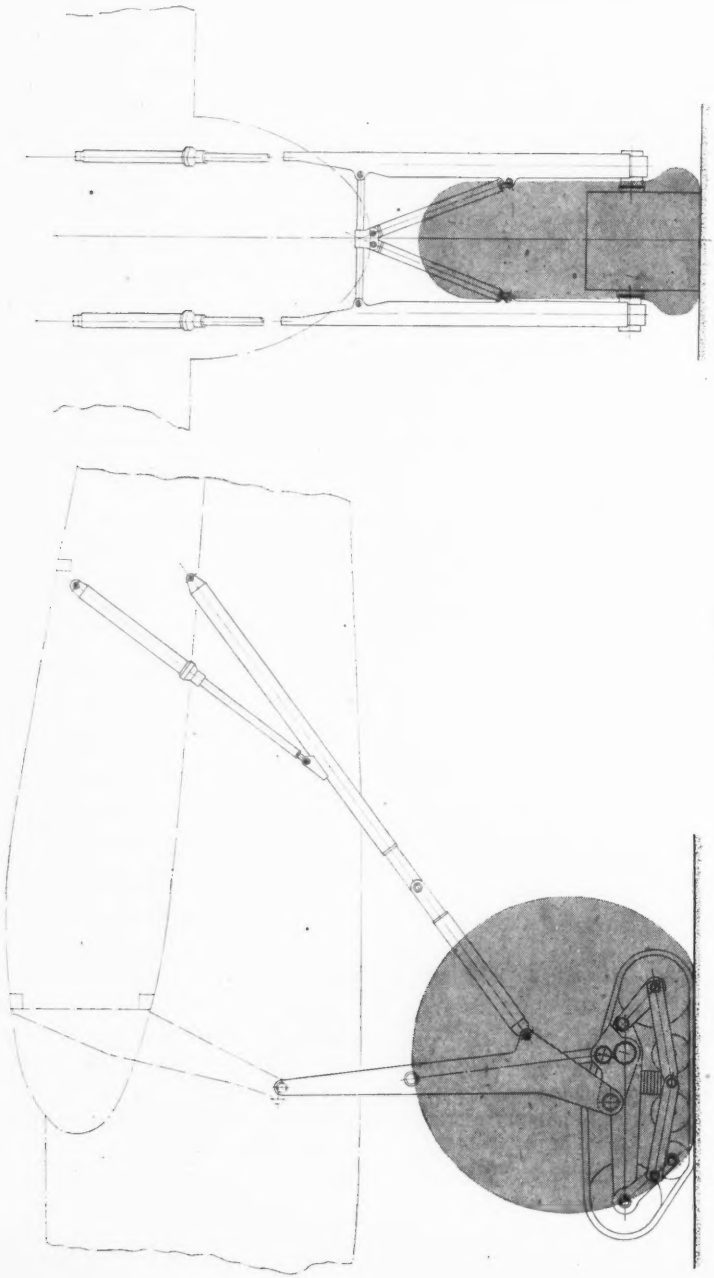

Fig. 2

it has been found possible to operate from all but the wettest of aerodromes.

Tyre pressures of 70 lbs./sq. in. are now frequently used with prepared runways, and we are advised by competent civil engineers that reinforced concrete runways are a practical possibility for the heaviest projected aeroplanes (up to 360,000 lbs.) with tyre pressures of 90 lbs./sq. in., although this may not represent the limit. Fig. 3 shows ranges of tyre sizes designed to operate at 35, 50 and 90 lbs./sq. in. inflation pressure respectively.

The reduction in the overall dimensions by the introduction of the range of higher pressure tyres is impressive. It is emphasised that the smaller high pressure tyre may be used with confidence, always assuming that a suitable aerodrome surface is provided.

The aircraft designer should be able to take considerable advantage of these smaller dimensions in arranging for the retraction of the wheels. The saving in weight by increasing the tyre inflation pressure from 35 to 90 lbs./sq. in. for an aeroplane weighing 40,000 lbs. is approximately 200 lbs., i.e., ½ per cent. of the all-up weight of the aeroplane. The use of the high pressure tyre, therefore, shows a substantial increase in the pay load of the larger civil type aeroplane.

I would like to emphasise the importance of this matter, not only for civil, but military aircraft. In order to use the smallest possible wheel, it is essential that prepared runways be provided.

For civil aeroplanes it is suggested that except for comparatively small feeder types, reinforced concrete runways must be provided, which will enable tyre pressures of at least 90 lbs./sq. in. to be employed.

Practical experience shows that whilst it is possible to provide runways which will stand up to these tyre pressures, careful attention must also be paid to the construction of the standings, and to the peripheral tracks.

Mr. Brian H. Colquhoun, in a paper recently presented before the Institute of Structural Engineers, stated that no limitations on aircraft should be imposed by the airport design. It is, therefore, suggested that the civil aircraft designer should take full advantage of the reduced dimensions of the high pressure tyre, and that the authorities responsible for military aircraft should bear in mind the advantage which could be gained by the development of temporary aerodromes with prepared runways.

Arrangement of the Wheels

The above comparison shows the substantial reduction in size and weight which is effected by increasing the permissible tyre inflation pressure.

A further saving in overall diameter and weight can be achieved by the use of multiple wheels in the heavier aeroplanes now projected.

Fig. 4 shows the effect of using 2, 4 or 8 wheels respectively on an aeroplane weighing 250,000 lbs. with tyre inflation pressures in each case of 90 lbs. sq. in. With 2 wheels the overall diameter is no less than 111in. by 35½in. wide; weight is calculated to be 7,680 lbs./aeroplane = 3 per cent. W. With 4 wheels the diameter is reduced to 80in. and weight to 2½ per cent. W. With 8 wheels diameter is still further reduced to 57in., i.e., approx. half that of the 2 wheeled arrangement, and the weight to 5,000 lbs. (2 per cent. W).

There would appear to be, therefore, a very strong case for the adoption of the multiple wheel arrangement for the large civil types of aeroplane now projected. It is realised that a part of the weight difference may be offset by some increase in the undercarriage structure necessitated by the multiple wheel arrangement. On the other hand, the smaller space required for the accommodation of the retracted wheels may make possible some reduction in the aeroplane structure.

Adequate braking can be provided with the multiple wheel arrangement; two tyres may also be mounted on a common wheel.

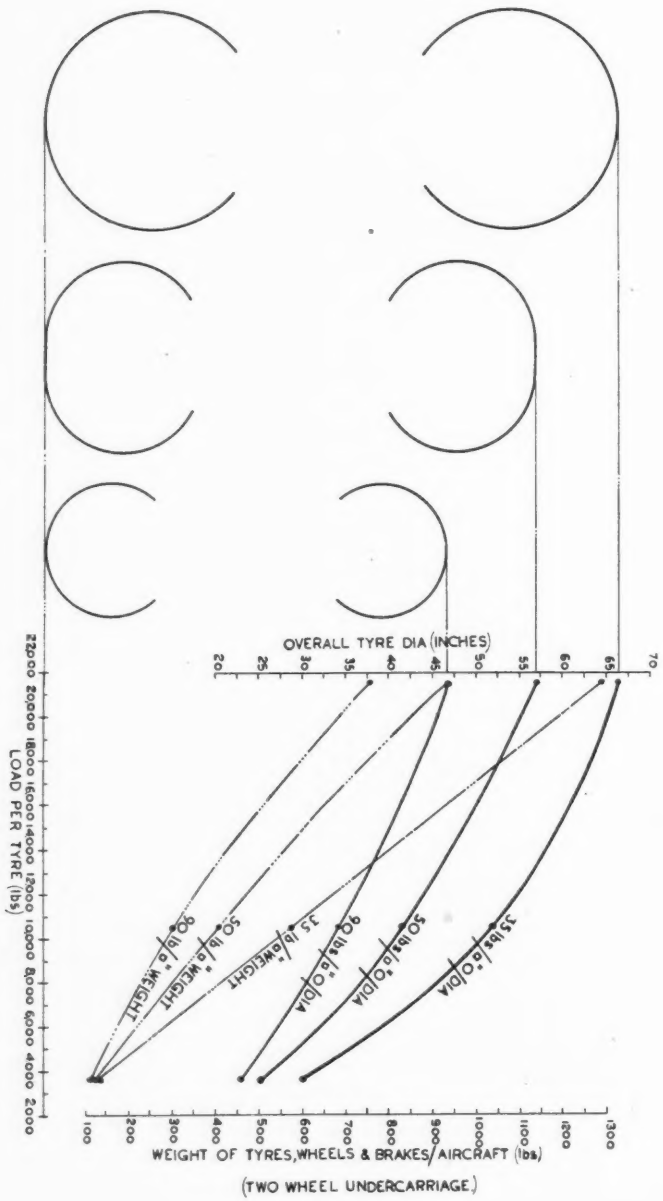
OVERALL TYRE DIA (INCHES)
20
25
30
35
40
45
50
55
60
65
70
LOAD PER TYRE (lbs)
22000
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
90 lb/sq in WEIGHT
50 lb/sq in WEIGHT
35 lb/sq in WEIGHT
90 lbs/sq in O/DIA
50 lbs/sq in O/DIA
35 lbs/sq in O/DIA
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
WEIGHT OF TYRES, WHEELS & BRAKES/AIRCRAFT (lbs)
(TWO WHEEL UNDERCARRIAGE)

Fig. 3

250,000 lb. AIRCRAFT.

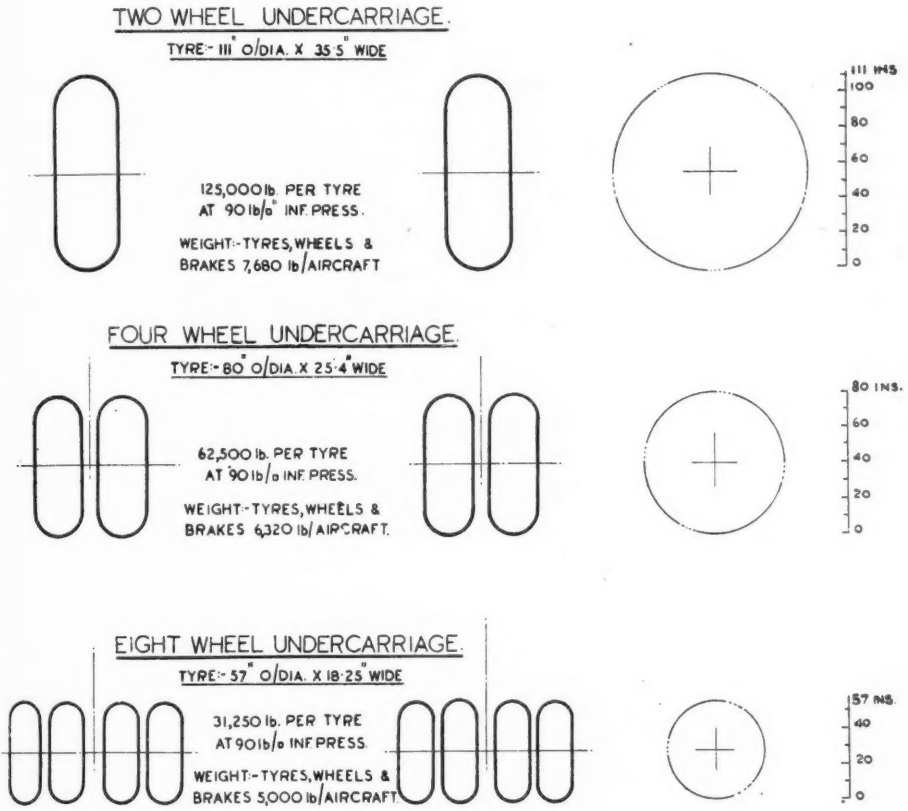

Fig. 4

This arrangement might facilitate the undercarriage and axle design.

The increased safety factor provided by the multi-wheel arrangement is a further advantage. The sudden failure of a large single tyre allowing one undercarriage to drop a distance of 2-3 ft. might be attended with serious consequences, whereas it is unlikely that more than one of the smaller tyres will fail at any one time.

Layout of the Tyre, Wheel and Brake Unit

I have already emphasised the careful consideration which is given in this country to the reduction in overall dimensions of the complete wheel assembly. There is a strong case to be argued for the general design of this assembly to be entrusted to one authority. In the U.S.A. it would appear that separate designers and manufacturers are responsible for the tyre, the wheels, the brake drum, the brake unit and the brake controls, with the result that in some cases unduly fierce brakes are used, resulting in rapid tyre wear. British wheel designs generally are better balanced—the tyre, wheel and brake system are designed as a complete unit, due regard being paid to the

distinct requirements of each component of the complete assembly.

The British designer has been handicapped by the inadequate or "soft" aerodrome, and the necessity to keep the tyre inflation pressure down to 35 lbs./sq. in. In order to achieve this without resort to an excessive overall diameter, a large cross-section of tyre and small rim diameter has been used (see Fig. 5). Whilst the small brakes in these wheels were sufficient for the loads intended at the design stage of the aeroplane prior to the outbreak of hostilities, these brakes are not entirely adequate for the higher loads and landing speeds used to-day.

It will be noted, therefore, that with the introduction of prepared runways and the adoption of the higher pressure tyre, it has been possible to improve the effectiveness of the wheel brakes. The general design shown in Fig. 6 represents current British practice. It is interesting to note that many American designs are markedly similar in principle and that in this instance the lead has been taken in this country. We were the pioneers of the magnesium cast wheel and the inflated sac brake—both developments which have been widely followed in the U.S.A.

The low specific gravity of magnesium makes possible the production of robust castings of light weight.

Advantage is taken of the low specific gravity to design a simple wheel casting by the elimination of troublesome cored holes and pockets, without any appreciable increase in weight.

This comparatively simple design, allied to close co-operation with the foundry, has resulted in the production not only of very large quantities, but of uniformly sound magnesium castings, which have given exemplary service under arduous conditions.

General soundness of castings is considered of paramount importance, and apart from the usual routine chemical and physical tests made at the foundry, we carry out a percentage break-up test on all wheel and brake castings. This test is made by carefully fracturing the finished heat treated casting under a hydraulic press, and examining each fracture. It is a feature of this magnesium alloy that fractured areas of micro shrinkage show up coloured, and are therefore easily detected. After experience of particular foundries, it is possible to judge the deterioration in physical properties by the particular colour of the fracture, e.g., a pale yellow colour generally means little loss in strength, whereas a grey fracture may result in a reduction in physical strength of as much as 60 per cent.

Whilst X-ray examination has been carefully explored, we have found this to be an impracticable method for examination of the complete wheel casting, although this method is occasionally used to check a particular region which may be suspect and accessible.

The general soundness and particularly the total absence of flux inclusions has probably helped in no small degree with corrosion problems.

Under exceptional circumstances, such as adverse storage conditions, and where aeroplanes have been operating from salt flats in the Near East, corrosion failures have been reported, but 15 years' practical experience has shown that, provided reasonable precautions are taken, no corrosion trouble is to be anticipated, even when magnesium wheels are used on carrier borne aircraft.

For amphibian and other types of aeroplanes where the wheel comes into direct contact with sea water, we have successfully employed the aluminium-magnesium (Birmabright) alloy, in conjunction with stainless steel components. These wheels have been used for some years now on the "Walrus" and for beaching chassis of flying boats, where the wheel is immersed in salt water. We have experienced no trouble whatever due to corrosion.

It is our opinion that the magnesium cast wheel is the lightest practical proposition, and is generally to be preferred to the aluminium

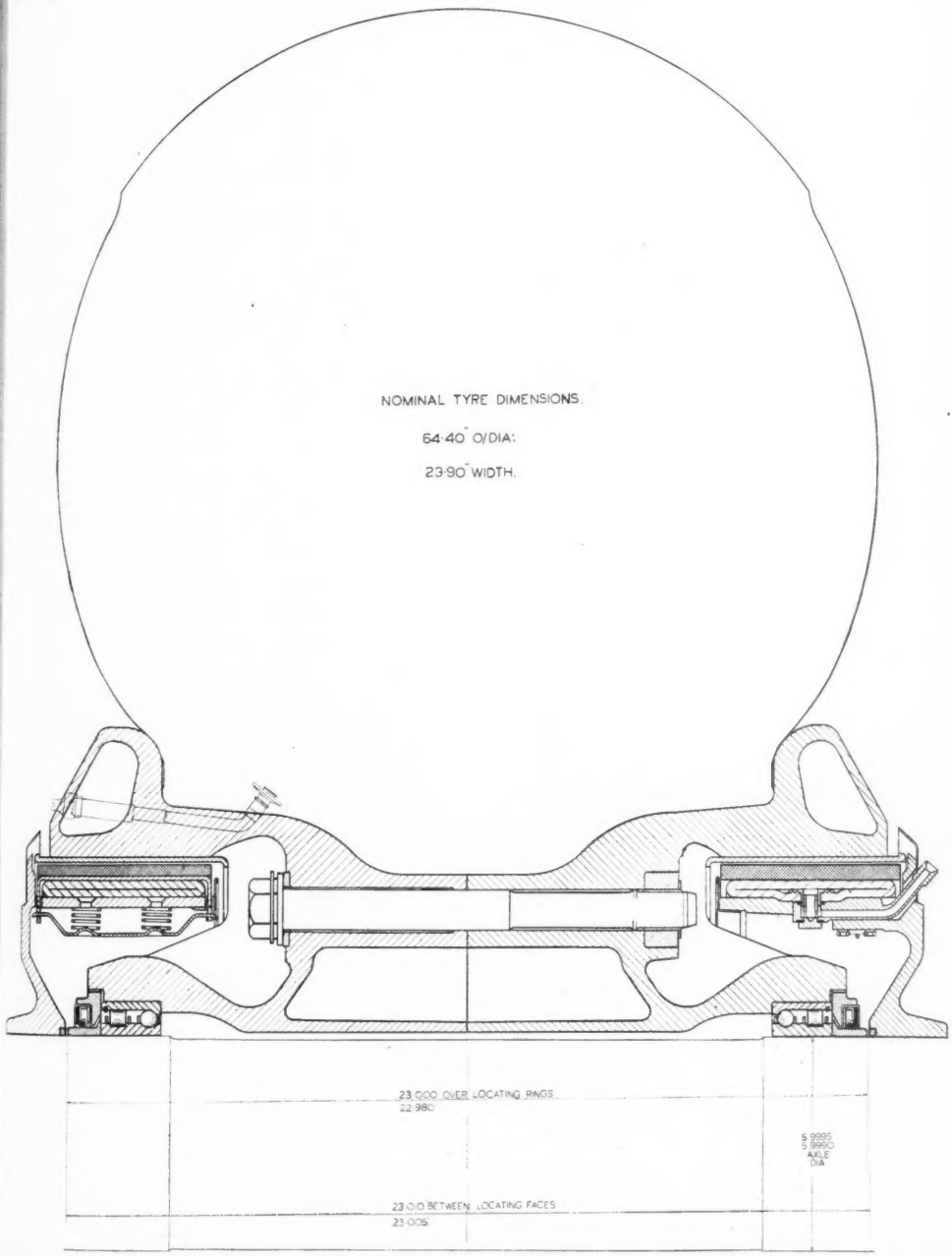
NOMINAL TYRE DIMENSIONS.
64·40" O/DIA:
23·90" WIDTH.
23·000 OVER LOCATING RINGS
22·980
5·9995
5·9990
AXLE
DIA
23·010 BETWEEN LOCATING FACES
23·005

Fig. 5

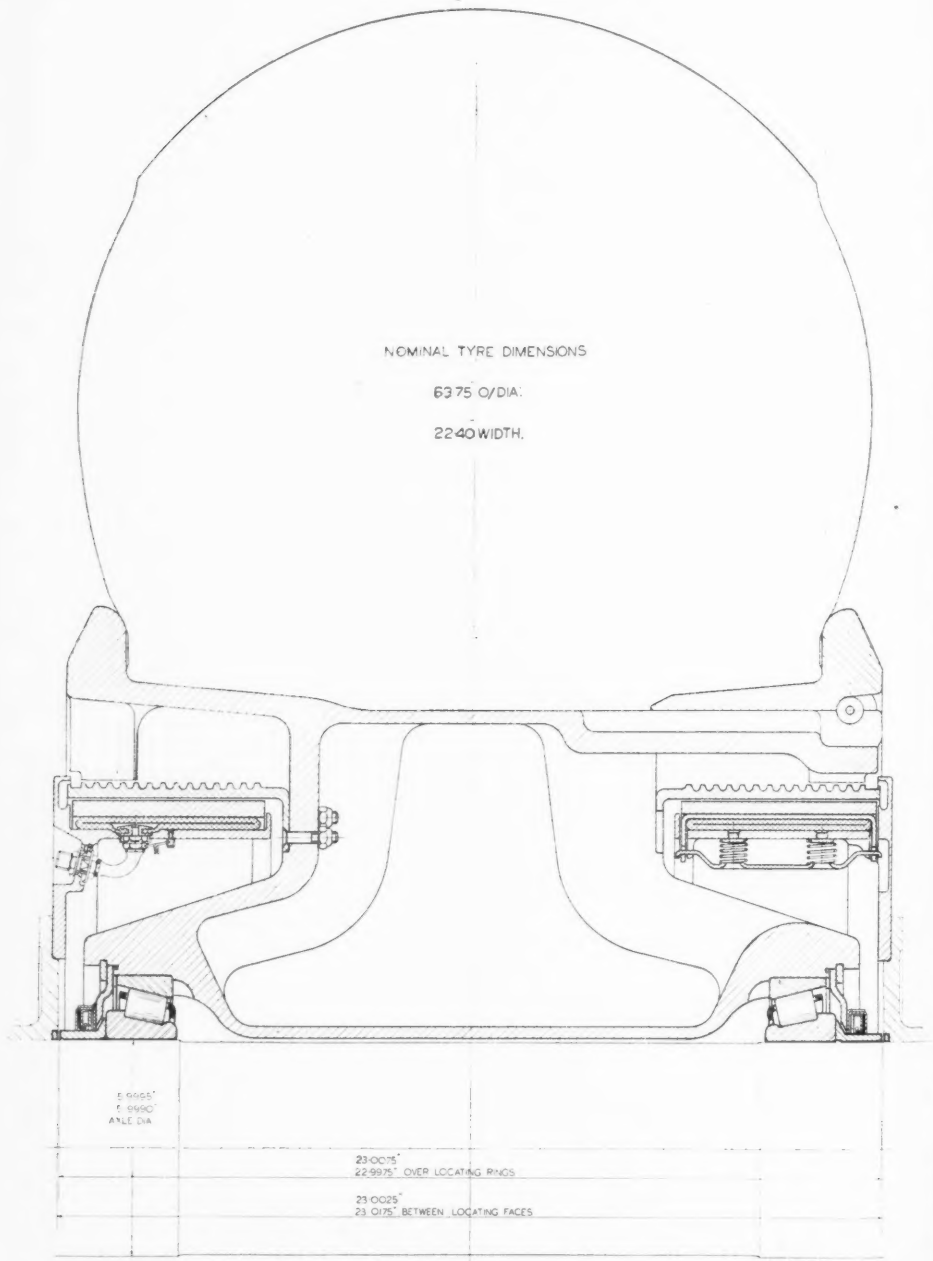
NOMINAL TYRE DIMENSIONS
63·75 O/DIA.
22·40 WIDTH.
5·9965"
5·9990"
AXLE DIA
23·0075"
22·9975" OVER LOCATING RINGS
23·0025"
23·0175" BETWEEN LOCATING FACES

Fig. 6

alloys. We find it is most difficult to produce sound aluminium castings sufficiently thin to take advantage of their higher physical properties.

During the period at the commencement of the war, when a shortage of magnesium was anticipated, we carried out extensive research in the uses of alternative materials. A comparison of the weights of a large wheel made in—

(a) Magnesium is ... 234 lbs.
(b) Aluminium is ... 286 lbs.
(c) Pressed Steel is ... 300 lbs.

Brakes

The aeroplane wheel brake is required to perform two main duties. Firstly, to arrest the aeroplane on landing, and, secondly, to steer the aeroplane whilst on the ground. Both these requirements are becoming more exacting with the considerable increases in landing speeds and weights, together with the reduction in the aerodynamic drag of the latest aeroplane types.

It has been difficult to assess the proportion of the kinetic energy of the aeroplane on landing which is dissipated by aerodynamic drag, friction, etc., and that which is absorbed by the brakes. In the past we have assumed these proportions to be approximately equal, but with modern designs and particularly tricycle types, it is probable that the wheel brakes are called on to dissipate some 70-80 per cent. of the total kinetic energy of the aeroplane.

In considering the performance of an aeroplane wheel brake it is useful to make an approximate comparison of its duties with that of the brake fitted to a heavy commercial road vehicle. The example given below does not pretend to be an accurate estimate of the temperatures reached, but is given merely to emphasise the severe conditions which are imposed on the aeroplane brake, not only by high speed of the aeroplane, but also by the extent to which we have reduced the weight of the brake drum:—

AEROPLANE.

65,000 lbs. all-up weight.
Landing speed 80 m.p.h.
50 per cent. kinetic energy dissipated by brakes
= 7,000,000 ft. lb.
= 9,000 B.T.U.s
Total weight of brake drums = 100 lbs.
Temperature rise = 750°F.

COMMERCIAL VEHICLE.

12 tons (26,880 lbs.).
Speed 50 m.p.h.
100 per cent. kinetic energy dissipated by brakes
= 2,250,000 ft. lb.
= 2,892 B.T.U.s
Total weight of brake drums = 260 lbs.
Temperature rise = 93°F.

When brakes were first introduced it was the general practice to adopt the conventional rigid shoe design as commonly used for road transport work. As the duties of the aeroplane brake have become more severe, it is interesting to note that the inflated sac type which has been used on the majority of British aeroplanes for over ten years, is now fitted to several of the larger American aeroplanes.

The principal advantages of this type of brake are:—

(a) The distortion of the brake drum caused by the high operating temperatures can be accommodated by the flexing of the expanding sac.
(b) The large area of contact between the brake lining material and the brake drum.

Some difficulty has been experienced in providing a brake lining which will stand up to the high temperatures of the brake drum—particularly when the brakes are used for prolonged taxying to dispersal points, or for repeated landings, during instructional training.

A considerable programme of research has already been carried out, and is, in fact, still

being continued, with a view to providing improved brake lining materials.

The general requirements of the aeroplane brake demand that friction linings shall:—

(a) Maintain stable coefficient of frictions up to 800°C.

(b) Possess reasonable wear resistance over the same temperature range.

(c) Maintain their opposing metal surfaces in good condition.

(d) Possess sufficient mechanical strength to operate with the flexible support of the air sac.

(e) Possess good heat insulating properties to protect the more vulnerable parts of the brake mechanism.

These requirements have been met by materials having an asbestos base bonded by a variety of thermo-setting synthetic resins. Broadly speaking, most materials of this type give the requisite mechanical strength and heat insulating properties, but stability of friction, particularly at the higher temperatures, is largely controlled by the characteristics of the synthetic resin bond, which are mostly of the phenol-formaldehyde type. These tend to exude liquid at temperatures in excess of 250°C. This causes a marked drop in the coefficient of friction, commonly known as " fade," which may be permanent if this film becomes carbonised on the working surface of the lining. Recent development has concentrated with considerable success on minimising this characteristic by modifications of the resin itself and by suitable treatments of the finished brake linings.

We have for some time been investigating the possibility of adopting the " sintered linings." This consists of a moulded mixture of metallic and non-metallic powders, including copper, tin, iron, silica and graphite. These are fused to a metal alloy matrix in which the other constituents are dispersed as inclusions. These sintered materials may be capable of operating at high temperatures with a sustained coefficient of friction. Unfortunately, they are heavy and their high thermal conductivity introduces other complications, which preclude their immediate adoption. It is noted that this sintered lining is already used in some brake designs evolved in the U.S.A.

Whilst this is a development which is still receiving close attention, recent improvements in the asbestos types have succeeded in maintaining a steady .30-.35 coefficient of friction up to 800°C. Full advantage of this development has been taken, with the result that the tendency to fade appears to have been eliminated, even under the most severe conditions of braking.

Retardation

Some divergence of opinion would appear to exist as to the rate at which it is required to stop the aeroplane.

It is most undesirable that, except possibly in the case of an emergency, it should be possible for the pilot to lock the wheel on the runway. When this is done, the rate of wear of the tyre tread at high speed is most serious. Fig. 7 shows a tyre and wheel in which the

Fig. 7

tyre has been completely destroyed and a flat worn on the wheel in the space of six seconds.

The maximum coefficient of friction between the tyre and dry rough concrete is of the order of .9/1.0, but it is suggested that a retardation of .3 g should be sufficient for all normal requirements. We should welcome the views of aircraft designers and operators on this opinion.

Alternatives

In considering alternative methods of stopping the aeroplane or of improving existing

brake designs, it is important to compare the weight of any proposal with existing brake design.

I have in mind that liquid cooling of the brake drums has been frequently proposed. Detailed examination of this proposition shows, however, no economy in weight, and that it is difficult to evolve a practical design.

Electrical braking systems are generally heavy.

Reversible airscrews would appear to be a practical proposal—particularly for the larger multi-engined types.

No data is available on the weight involved in this system. It is possible that civil operators may not be prepared to rely on a braking system which would be ineffective in the event of engine failure, and it is probable that wheel brakes would still be required for taxying.

It is understood that whilst arrester gear is used on deck landing aircraft and for certain military purposes where it is desired to stop the aeroplane in a short distance, the general opinion is that such a system is heavy, due to the necessity of reinforcing the aircraft structure.

More consideration might be given to this braking method, particularly if the landing run is increased to that of the wheel braked aeroplane.

Tricycle Aeroplanes

We have recently carried out a series of tests on a high performance tricycle aeroplane, and have come to the conclusion that unless it can be arranged that the nose wheel is pressed against the ground with a force at least equal to the normal static reaction, it is better to dispense with the nose brake. Very little increase, if any, was effected in retardation by the application of the nose wheel brake, whereas it was difficult to prevent locking of the nose wheel, with disastrous effects to the tyre.

Brake Controls

The inflated sac type of brake is operated by either compressed air or hydraulic pressure.

From the brake operational point of view we prefer compressed air, for the following reasons. Lag in applying and releasing the brakes is reduced to the minimum—vibration is reduced—this can be extremely troublesome with hydraulic brake units—reduced weight.

It is appreciated, however, that it may be desirable to reduce the number of auxiliary power services, and that for this reason hydraulic operation may be preferred on new designs.

There is no fundamental difficulty in meeting this requirement—in fact, large numbers of aeroplanes have been operating for several years with hydraulic brakes.

In this country we have preferred the hand operated brake with a differential relay valve coupled to the rudder bar.

In the U.S.A. independently operated foot pedals are largely employed.

I suggest that the English system is a more natural control for the pilot—it is difficult to apply the brake by pressure of the toe when the pilot's leg is already extended in pushing the rudder bar forward.

Expressions of opinion on this subject would, however, be helpful, particularly at the present juncture when new systems of hydraulic control are under investigation.

I am glad to have this opportunity of expressing to all my friends in the aircraft industry my appreciation of their co-operation in the development of aircraft wheels and brakes.

I would like to pay tribute to the encouragement which Mr. Grinsted and his colleagues at the Ministry of Aircraft Production have always extended to my Company. The facilities for experimental work which they have placed at our disposal have been of inestimable assistance.

The extent to which we have been able to employ magnesium in these aircraft products is largely due to the technical advice and

practical co-operation which we have received from Mr. E. Player.

I am indebted to Mr. S. Camm, Mr. Geo. Dowty and Major R. H. Mayo, who have been most helpful in the preparation of these notes.

In conclusion, my sincere thanks are due to the Directors of the Dunlop Rubber Company and my colleagues of the Technical Departments.

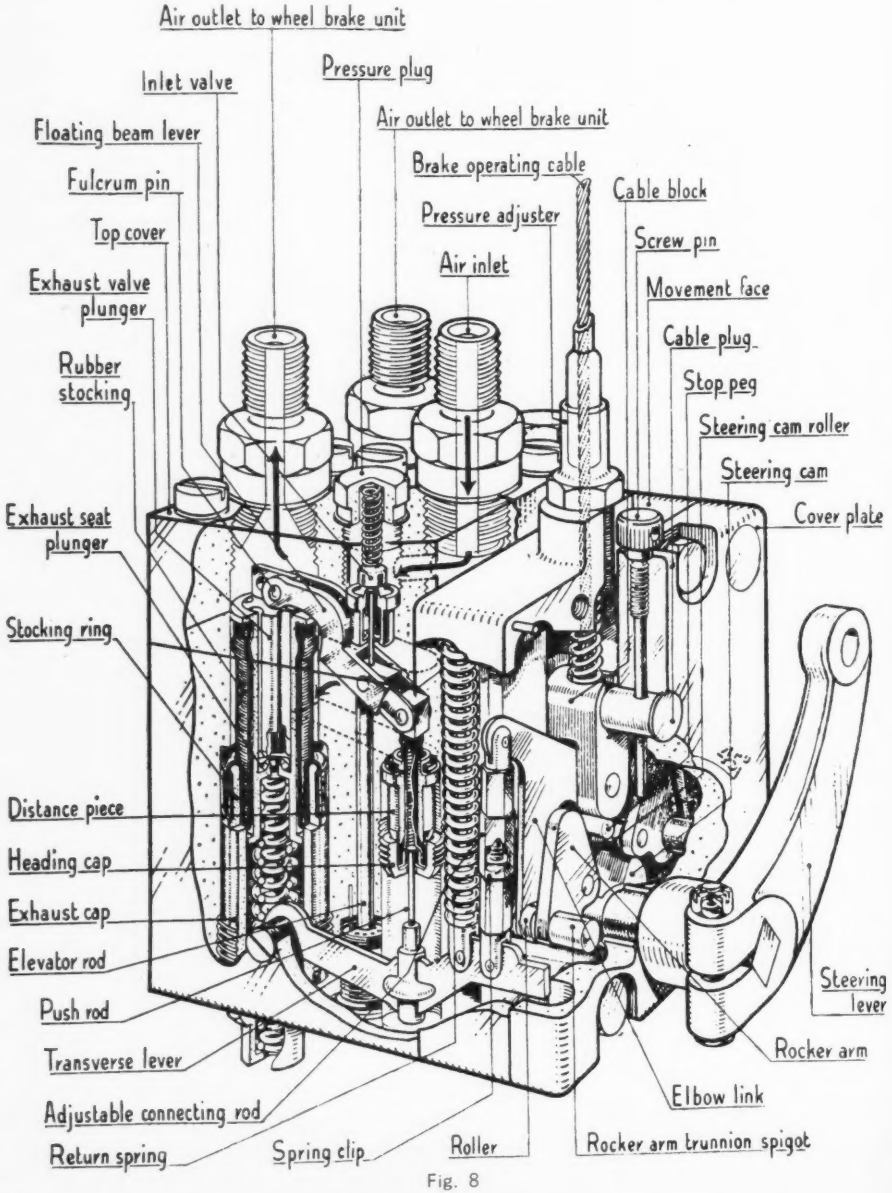

Fig. 8

DISCUSSION

The CHAIRMAN said that Mr. Wright's most interesting, practical and useful review of aeroplane wheels and brakes had served to emphasise that the rapid development of aeronautics called for the application of ever-increasing refinement and engineering ability.

One would like to hear more of the effect of the large wheels and brakes on the aerodromes on which the aircraft landed, and of the construction of aerodromes. One would imagine that the introduction of jet propulsion would render braking problems even more difficult than with the normal type of prime-mover on aircraft.

Mr. F. ROWARTH (Ministry of Aircraft Production) (Fellow): The tyre problem might appear to be very simple. bearing in mind that the life of a motor car tyre was, say, 20,000 miles; but when one found that the life of the tyres on a large bombing aircraft is sometimes limited to only 12 landings, one might be inclined to feel that the tyre producers were not doing their job, that they were not trying. Therefore, it was necessary that a paper such as that of Mr. Wright's should be presented. The figures of energy dissipated by aeroplane brakes, in terms of British thermal units, related to the total weight of brake drums, and the comparison with the figures relating to a commercial road vehicle, provided sufficient evidence that every day experience with road vehicles had just nothing at all to do with the problem of the aeroplane wheel and tyre. One hoped that more and more specialists would present similar papers, which would promote sympathy with the specialists and their difficult problems, especially if the papers were backed up by educational films of the type which Mr. Wright had exhibited.

A matter on which he would quarrel mildly with Mr. Wright was that he had not finally buried the bogey of the apparent advantages to be gained from rotation of the aeroplane wheel immediately before the tyre touched the ground. That proposal had been a hardy annual during the last few years, and one hoped that he would dispose of it once and for all, either by an addition to the paper or in his reply to the discussion.

The CHAIRMAN: He had been asked by Mr. George Dowty, of Dowty Equipment, Ltd., who unfortunately had been involved in a motor accident three weeks earlier, to convey his regrets that he was unable to attend the meeting. Mr. Dowty had been in close collaboration with Mr. Wright, and had made the following written contribution to the discussion:—

Mr. G. DOWTY (Fellow) (contributed): He regretted that he was prevented by doctor's orders from attending Mr. Wright's lecture. He had hoped that Mr. Bound, his Technical Director, would have represented him, but at the last moment he had also been prevented by illness from attending and he had therefore asked Mr. Hunt to read some notes which he had intended to put.

In the first case he would like to pay tribute to the initiative and efforts of Mr. Wright during the last 15 years. Those like himself who have had continual dealings with Mr. Wright could not speak too highly of the work he had done.

The Dunlop Company had for 15 years pioneered that type of brake in which the friction elements were pressed to the drum by means of an inflatable tube. Such a brake gave smooth operation as even contact was ensured over the whole braking surface. It had always seemed to him that this type of brake was obviously correct for a lightly constructed wheel. America had retained the two or three shoe type hydraulically operated brake, but had now adopted the British designs, and this was a compliment to the foresight of the English wheel and brake companies.

With reference to the lecturer's remarks on caterpillar track development, it should be mentioned that the volume of the caterpillar track was only about 1/5th of the present equivalent pneumatically tyred wheel, and if

additional weight was involved in the track itself, substantial saving could be made in the weight of the aircraft structure by the smaller space required for housing and the smaller doors for closing the apertures in the wing and fuselage.

It should be noted that the caterpillar track had advantages over the pneumatic tyre in that there was no undamped air volume and the whole of the springing could be damped, troubles due to tyre bursts were eliminated, more powerful braking could be employed, and there was less tractive resistance. This latter condition had been established by tests on experimental tracks.

If tyre pressures of 100 lbs./sq. in. were permitted (and he saw no reason why this should not be so) and if the tyre manufacturers could reduce the cross-sectional area of the tyre by varying its present shape, it was possible that the pneumatic tyre will show advantages over caterpillar tracks.

He believed that the tyre companies were now working on these lines, and he was looking forward with interest to the result of these experiments.

With reference to the multi-wheeled undercarriages and the substantial weight saving which the lecturer had indicated, it should be made perfectly clear that these figures were unrealistic as they took no account of the additional weight of the undercarriage structure. The larger the number of supports and the longer the axles, the greater would be the undercarriage structure weight. In addition, manufacturing costs and maintenance difficulites would be increased.

With reference to four-engined bombers, the wheel, brake and tyre equipment weighed substantially more than that of the undercarriage structure. The actual figures for the Lancaster were 1,530 lbs. for the wheels, brakes and tyres, as against 1,130 lbs. for the undercarriage structure, which showed that the wheel equipment is 400 lbs. heavier, The wheel, brake and tyre manufacturers had more scope for reducing weights than the undercarriage manufacturer, and he hoped that with the new designs of wheels and tyres at present under consideration, they would achieve a substantial saving in weight. He would be interested to know what reductions Mr. Wright considered would be possible wth present undercarriages when higher pressure and smaller sectioned tyres were used.

He would like to make a plea for a greater degree of standardisation of aircraft wheels and brakes.

If we were to achieve the greatest economies of manufacture and obtain the resulting benefits such as easy maintenance and ready supply of spares, we should endeavour to reduce the number of wheel and brake designs. At present, the number of wheels varying in such particulars as hub dimensions and axle diameters were enormous, and could very well be reduced to a fraction of their present number. It was obvious that every aircraft constructor enforced the wheel manufacturer to provide a wheel exactly to meet some particular requirement, but he felt that with a little effort on the aircraft manufacturer's part they could readily take standard wheels instead of special design.

Such a change could only come about by action on the part of the Government to enforce a measure of standardisation on the aircraft industry. He felt this would be well worth while. He saw no reason why aeroplanes within a certain weight band should not use the same wheel, brake and axle assembly, using, where necessary, an oversized tyre for the higher end of the weight band.

With the obvious competition from America, he was sure that this was one way in which the British Aircraft Industry could obtain substantially lower cost of wheel and undercarriage equipment.

Mr. H. G. Conway (Messier Aircraft Equipment, Ltd.) (Associate Fellow): Whilst everyone was agreed that increased tyre pressure was desirable for future military aircraft designs, it was interesting to note the

opposing viewpoints of two chief designers with whom he was talking recently in connection with the tyres for their new civil types. The one had wanted to exceed the 70 lb./sq. in. which had become more or less standard, and to increase the pressure up to 90 lb./sq. in. or more; the other had wanted to restrict tyre pressure to 40 or 50 lb./sq. in.

The first was interested only in the size of his wheel and the problem of stowing it away. The second was interested in tyre life and had insisted on reducing tyre pressure so that the tyre replacement cost to the airline operator would be at a minimum. Mr. Conway asked if Mr. Wright would express an opinion on that aspect of tyre life, for it seemed to be of some importance.

Commenting on Mr. Wright's comparison of the American practice of having separate designers for tyre, wheel and brake, with the British practice of having a single designer for the whole assembly, he believed there was little advantage to be gained by having a common designer for tyre and wheel assembly, and suggested that the fact that it was so in this country was purely coincidental. Surely, he said, a tyre, which was a mixture of rubber and cord and involved physics and chemistry, was a job for a different type of engineer from the man who designed the wheel and brake gear, which after all was precision mechanical engineering.

One of the peculiar facts about English aircraft was the very large number of different tyres in use; he believed that at one time during the war no two aircraft had used the same tyre. That seemed to be due to the lack of a range of standard tyres. Going back a stage further, it was also due to the lack of a rim standard giving all dimensions of the rim profile and its diameter and width. The only standard he knew of was the I.S.A. standard Bulletin 20, which had been used, possibly exclusively, in Germany, France and Italy for some years. There was a very great need for a British rim standard to enable tyres of various makes and nationalities to be used on the same wheel. The average motorist would be very unhappy if only one make of tyre would fit his car wheels, and even more upset if he took his car abroad and could not obtain a spare. When one realised that aviation was much more international, and how much more inconvenient was the transport of aircraft tyres, it would be appreciated how important the matter could be.

Mr. Wright had referred almost exclusively to the bag type of brake which his Company had developed. Whilst it was true that some of that type of brake were used in the U.S.A., surely both shoe and disc brakes were also widely used there; and he believed the shoe brake was universal in Continental Europe, the German brakes in particular appearing to be highly developed. Disc and shoe brakes were also used on some types of aircraft in this country.

Mr. Conway illustrated a typical two-shoe hydraulic brake of the most advanced type and asked for Mr. Wright's opinion on its qualities or faults, as compared with the bag type of hydraulic brake. The shoe brake was of the two leading shoe type, with some self-servo action, and in view of its very small consumption of fluid at 2,000 lb./sq. in., it was very difficult to appreciate that its control could not be very much quicker than the low-pressure large-volume bag brake.

Recalling Mr. Wright's reference to proposals to cool the wheel drums by means of fluid, he illustrated an alternative proposal, i.e., the cooling of the shoes. In the case illustrated the shoes were of cast iron, and hollow, with fluid circulating in them. The brake lining was fixed to the wheel, and rotated. The superficial advantages, he said, were obvious, and he asked for Mr. Wright's opinion.

Another matter on which he asked for Mr. Wright's views was that of wheel and brake testing, and approval. At the moment, he said, wheels were not stressed in the usually

accepted manner, possibly because of the great difficulty of so doing. Proposals had been made to destruction-test the wheel by fitting the tyre and loading it hydraulically with water instead of air until failure. The static rating was then the failing load divided by the wheel factor (9 in England, 7½ or 8 in the U.S.A.). According to new proposals made at the Chicago Air Conference, brakes for civil aircraft must be proof-tested by so many stops on an inertia-testing machine. Although the U.S.A. had several of those machines, none was yet available in this country.

Finally, Britain's first two large machines (20,000,000 ft.-lb. K.E.) were now being built, one for the R.A.E.; and since the use of those machines might be obligatory, he would welcome Mr. Wright's opinion.

Mr. BRIAN H. COLQUHOUN: Being closely concerned with the planning and development of post-war aerodromes, he assured Mr. Wright that aeroplane tyre pressures could increase to 120 lbs./sq. in. or more without having any serious effect on the design of runways. In fact, an increase of pressure from 80 to 120 lbs./sq. in. in the tyres would make a difference of only about 2½ per cent. in the net cost of the runways of an aerodrome. But a matter which was much more important than that of tyre pressure was the number of wheels and the number of undercarriages on aircraft of the future. During the last year or two there had been a considerable amount of discussion as to the number of undercarriages that would be fitted as the weight of aircraft increased. If the number of undercarriages increased beyond two, difficulties arose immediately in regard to the drainage or the camber of the runways. For aircraft having only two undercarriages, the slope or camber of the runways did not matter very much. But if there were three or four undercarriages in line, then clearly when the aircraft landed some of the wheels would touch the ground before the others, and those which touched the ground first would be considerably overloaded temporarily unless special arrangements were made. It would be interesting to hear Mr. Wright's views on that problem. If it were concluded that runways must be flat, serious problems would arise, when one visualised runways 3,000 or 4,000 yards long and 200 yards wide; one could not drain an absolutely flat surface. On the other hand, Mr. Wright might say that runways should be cambered, and the aircraft would be fitted with undercarriages having wheels which would maintain the camber. That would be satisfactory if each aircraft always landed on its own runway. One could not guarantee that all runways would have the same camber. There would be a difference of height of as much as 6in. in the distance of 40 or 50ft. between the undercarriages. It must be remembered that already there were on the drawing boards aircraft having three undercarriages.

Asking for information as to the effect of the stiffness of tyre walls on the pressures imposed on the concrete, he said that one had to consider the area over which the load of the aircraft must be borne on the concrete runway; therefore, he would like to know whether the stiffness of the tyre was appreciable and was a matter which should be taken into account.

Mr. D. A. L. ROBSON (R.A.E., Farnborough): Commenting on the statement by Mr. Wright that the brakes of aeroplane wheels were required for two main duties, he suggested that the number of duties should be increased to four. The brakes were used first to hold the aeroplane stationary during the running-up of the engine prior to take-off; secondly, to bring the aeroplane to a stop when it had landed; thirdly, to hold it back during taxi-ing, in order to prevent it travelling too fast; and fourthly, to steer the aircraft. Those were really four separate issues, and each of them, with the possible exception of the last, might be a design criterion. With the increasing powers derived from engines, the static torque necessary to hold the aircraft stationary was

probably much greater than the torque required to retard the aeroplane during a landing. Therefore, that case became the critical case from the point of view of the maximum torque to be given by the brakes.

In regard to taxi-ing, it appeared that in very long distance taxi-ing around perimeter tracks, especially on crowded aerodromes or at night, when the velocity must be kept relatively low, the total energy to be absorbed or dissipated by the brakes was considerably greater than that which the brakes had to take in bringing the aeroplane to a stop after landing.

Further, the rate of energy input during landing was extremely high, and he suggested that it would be found impracticable to devise means of dissipating the heat during the extremely short period in which the brakes were applied during a stop. It might be possible, however, to dissipate the heat at the much lower rate which would take care of the braking during taxi-ing. Those were really two independent cases which might require quite separate treatment.

The problem of steering might affect more the design of the system for operating brakes rather than the brakes themselves. Mr. Wright had touched on the problem of hand and foot operation of brakes, but had not dealt with it in detail. In America and on the Continent of Europe, foot operation was almost universal, whereas in this country hand operation, with a rudder-bar-operated differential, had been adopted. It had been suggested that when taxi-ing aircraft across-wind or down-wind the loads which the pilot would have to exert in order to keep the rudder still might be quite high, and that it might be desirable for him to be in a position to lock the rudder bar during the process. If that were so, differential braking, for steering purposes, coupled to the rudder bar, became impossible, whereas with independent valves operated by pedals on the rudder bar it remained practicable.

With regard to steering an aeroplane by means of the brakes, Mr. Robson asked for the opinions of aircraft constructors, and possibly of users, as to whether the duty of the brakes in that respect could be dispensed with by using steerable nose-wheels or steerable tail-wheels on future aircraft.

The foot operation of brakes had one further advantage, in that it allowed the use of foot power actually to perform the braking operation. In the British system the brakes were always operated either by compressed air obtained from an engine-driven compressor, or by hydraulic power. In a foot-operated scheme, however, on small aircraft we could adopt brakes similar to the standard motor car brakes, say, of the Lockheed type, which used hydraulic transmission for their application, but did not require some separate source of power. It was not easy to assess the possible maximum sizes of aircraft which could be braked satisfactorily by means of power derived from the pilot; but the best opinions he could get seemed to indicate that, using expander tube brakes, it would be limited to aircraft of up to about 8,000 lbs. all-up weight, whereas with two-shoe brakes it would go up to the order of 12,000 and possibly 18,000 lbs. with multi-disc brakes. The ability to use brake operation of that type simplified greatly the installation in the aeroplane, and he urged that such a scheme should not lightly be thrown aside by reason of a rigid standardisation of hand operation with rudder bar differential.

Commenting on Mr. Wright's suggestion that it should be made impossible for the pilot to lock the wheels of an aircraft on the runway, Mr. Robson pointed out that the landing characteristics of an aircraft during the early part of the actual landing run were such that the weight which it imposed on the runway was very small; a braking torque which was capable of locking the wheels at that stage might be quite insignificant when the full static weight of the aircraft was employed, towards the end of the run. That really meant that, so long as the pilot had

control over the brakes, he was always capable of locking the wheels. Furthermore, the coefficient of friction between tyre and ground varied quite widely as between runway and runway, and in fact with weather. If, therefore, the maximum possible braking torque were restricted to that which would prevent the pilot from locking the wheels, even with the full static load, on the poorest aerodrome, he would then have far less possible braking effort than he could usefully employ on a good runway.

Finally, recalling that the only type of wheel referred to by Mr. Wright was the magnesium alloy cast wheel, Mr. Robson asked for his views on the possibilities of using magnesium forgings for building up wheels in future, for that would enable him to use better strength materials and probably thinner sections.

Mr. A. DAVENPORT (Westland Aircraft, Ltd.) (Fellow): He recalled the early difficulties experienced with brakes which consisted of a drum and a wire; and with the Bendix and Goodyear brakes, which were just mechanical Servo brakes. His Company, he said, had been very pleased to co-operate with Mr. Wright in 1925 and to introduce, with him, power-operated brakes. There was no question that that was a grand move; he hoped that they would continue to use power-operated brakes and, if possible, turn over to hydraulic, for it was much better to have two systems on an aircraft rather than three. At the moment there were three systems on an aircraft—electric, hydraulic and pneumatic—and if the pneumatic could be eliminated, as had been done already in respect of gun firing, they could reduce the number to two. Maybe in the future they would be able to reduce the number to one, and use the electrical system only.

Dealing with hand grip *versus* toe pedal control, he said that his Company, having tried both, were in favour of the hand grip control, and he believed also that the pilots preferred it.

The real headache at the moment was in connection with thin wings. In order to avoid compressibility, they were all trying to achieve small thickness chord ratio, and it was difficult to get the wheels into the wings, even with a tyre pressure of 90 lbs. per sq. in.; he hoped that something would be done to facilitate that. At present a nominal size of wheel was used, and it was necessary to allow in the clearances for tyre growth. He suggested there should be a minus tolerance on tyres, so that the size would never exceed the nominal diameter or width. Another important matter was that an undercarriage, after the first flight, altered its position, even to the extent of $\frac{3}{8}$in. or $\frac{1}{2}$in., and clearances must be sufficient to cover that.

Finally, he asked if Mr. Wright had thought of deflating tyres on the track.

Mr. R. H. CHAPLIN (Hawker Aircraft, Ltd.) (Fellow): He was very disappointed that Mr. Wright had disposed of hydraulic brakes with more or less a wave of the hand, particularly as he had stated in the paper that there was no fundamental difficulty in meeting that requirement and that in fact large numbers of aeroplanes had been operating for several years with hydraulic brakes. Commenting on Mr. Davenport's reference to the advisability of eliminating unnecessary services on aircraft, he said it seemed that the retention of the pneumatic service was due mostly to its use in connection with the brakes.

The reference to the Dowty caterpillar track was particularly interesting, because it raised again the question of the control of re-bound energy. Re-bound energy was a great nuisance in landing, and with a pneumatic tyre there was bound to be a lot of unabsorbed energy which was restored. He would like Mr. Wright to confirm that if an attempt was made to produce a tyre which would absorb this energy it would get impossibly hot under normal running conditions.

Expressing agreement with Mr. Colquhoun that it would be difficult to ensure that the

outer wheels of the multi-wheel aircraft would not become overloaded temporarily when the aircraft was landing, he said the problem might be solved by an articulated arrangement; but he suggested that that was a very difficult matter to arrange.

Connected with the question of the sideways retraction of undercarriages, he said he would like to obtain evidence of the effect on tyre wear of rake or " lean over " of the wheel in front elevation usually associated with this type of layout.

Finally, it was very nice to know that Mr. Wright, in his dignified position as a General Manager, was still able to talk as an engineer.

Mr. R. S. STAFFORD (Handley Page, Ltd.) (Fellow): He wished to draw attention to the problem of tyre creep, which had caused considerable difficulty in operation. The more recent British types of wheels, he said, were better than those produced at the beginning of the war, but tyre creep was still a problem and operators had to keep a very watchful eye on it. He asked what developments Mr. Wright had in hand to eliminate it.

With regard to tyre wear, all were familiar with the puff of smoke produced when a modern heavily-loaded aircraft landed, and it was reasonable to suppose that a considerable proportion of the tyre wear occurred on first impact. He asked Mr. Wright whether it would be possible to save appreciably on weight of covers if the wheels were spun up before impact; if so, it would be worth while developing the necessary mechanism, and especially if tyre life were considerably lengthened thereby.

There had been some difficulty recently in securing agreement among aircraft designers as between the values of brake torque published and those realised on the actual brakes. The method which he and his colleagues had used had been to find the deceleration by plotting the space-time curve for the aeroplane when coming to rest from about 60 m.p.h. with brakes on. In general, it was found that brake torque values realised were not more than about 60 per cent. of the makers' figures, and he believed that similar work at the R.A.E. had produced the same result. He asked if Mr. Wright could suggest why such low brake torque figures were realised in practice.

Mr. S. M. PARKER (Lockheed Co.): He asked if Mr. Wright could distinguish between the increase of weight on the wheel itself and on the tread, the cover and the tube. He would like to know whether those increases were roughly equal in each case, or whether there was a larger proportion in one as compared with the others.

Secondly, what were the critical cases for the scantlings of the wheel and tyre? Were they solely the taxi-ing cases, and if not, why was it that a high-performance undercarriage, which had a very much lower maximum reaction, did not appear to help them on the tyres?

Thirdly, with regard to hand-operated *versus* pedal-operated brakes, he asked what happened, from the pilot's point of view, on a fairly large aeroplane taxi-ing slowly in a side wind, and using the present-day conventional type of control. Would not a very large load be thrown on to the rudder bar, and did not the other type of system render it possible for the pilot to lock the rudder bar and control the aeroplane by the pedal movement? He believed many British pilots had become accustomed to the American type of control and had said that they liked it; but he had yet to hear evidence of the reverse attitude.

Mr. GUY MORGAN (Messrs. Guy Morgan and Partners): He confessed that in a way he felt that he had been invited into the lions' den, because he represented perhaps the spectator, who sometimes was able to see quite a lot of the game. After acknowledging the pleasure it had afforded him to have collaborated with the aircraft industry, he said he had been told recently that runways which were now being planned would have to be reduced considerably in size. Looking at the matter from the

engineering and the town planning points of view, very long runways did give rise to a serious problem. Very large aircraft were envisaged, and he asked for Mr. Wright's views as to what were the limiting factors, bearing in mind the adoption of new forms of propulsion, the loads that would be imposed, the use of multi-undercarriage machines, and so on. It was necessary to arrive at some figures indicating the lengths and widths of the runways that would be required during the next 10 or 15 years.

Major R. H. MAYO (Fellow) (contributed): Mr. Wright had brought out the important point that the total weight of tyres, wheels and brakes, expressed as a percentage of all-up weight, increases with the size of aircraft. The dimensional law under which structure weight tends to increase with size was well known, but so were the various ways and means by which designers have been able to counter this law in the aerodynamic design of the aircraft. But tyres, wheels and brakes fall into the category of engineering rather than aerodynamic practice, and the figures quoted by Mr. Wright show that even the great advances made had not enabled the dimensional law to be countered completely. Mr. Wright gave the percentage weight as $1\frac{1}{2}$ per cent. W. for the 10,000 lb. aircraft and 3 per cent. W. for the 250,000 lb. aircraft, assuming a conventional 2-wheeled undercarriage in each case. It would, he thought, be a matter of great interest if he would give an indication of the form of the curve on which these two points lie. Was it substantially a straight line, or did the slope rise more rapidly as all-up weight increases? In either case, but particularly of course in the latter, Mr. Wright had issued a warning to those who believed there was no limit to the feasible size of land type aircraft.

But those who, like himself, believed that the flying boat offered the best solution for the very large aircraft, would duly note that this particular warning applied only to the landplane; they would see a clear argument for the flying boat even at the top weight of 250,000 lb. considered by Mr. Wright. In case it should be thought he was over-emphasising the importance of so small a loss as $1\frac{1}{2}$ per cent. W. he would mention that for the 250,000 lb. size of aircraft this represented 14 or 15 passengers.

But it was fair to point out that Mr. Wright had already provided a partial solution of this problem of increasing weight. When dealing with the question of different wheel arrangements he showed that for an aircraft of 250,000 lb. all-up weight the 8-wheel undercarriage results in a reduction of 2,680 lb. as compared with the 2-wheel undercarriage, or roughly 1 per cent. of the all-up weight. If the 8-wheel undercarriage were applied to the 10,000 lb. aircraft it would certainly not knock off 1 per cent. W. from the $1\frac{1}{2}$ per cent. W. of the 2-wheel undercarriage, so Mr. Wright has definitely indicated a way of countering the dimensional law to some extent. But as he pointed out, the 8-wheel undercarriage will also have secondary effects on weight, and the resultant of these may appreciably reduce the total saving in weight on the 8-wheel undercarriage. So the very large aircraft cannot altogether escape from the dimensional law so far as undercarriage weight is concerned.

But apart from the question of weight, Mr. Wright had pointed out a very important advantage of the 8-wheel undercarriage for large aircraft. Mr. Wright said that the failure of a single tyre may have serious consequences, but Major Mayo suggested that he might have gone further and said "disastrous" consequences. It should be remembered that these very large aircraft would be absolutely dependent on the prepared runway, and if a tyre failure caused the aircraft to leave the runway the result might quite easily be disastrous. It seems to him that for these very large aircraft, the multi-wheel undercarriage was as important a safeguard as the multi-engine power plant, and he would go so far as to suggest that it

should be made a condition for airworthiness.

He would like to thank Mr. Wright for his kind reference to himself, and to congratulate him not only on the paper itself, but also on the extremely interesting films which he was able to show.

Group-Captain A. F. SCROGGS (Fellow) (contributed): He should like to take this opportunity of putting in an earnest plea for a change in our system of operating brakes, and he suggested that the present is a particularly favourable time for re-considering this important point, which in the ordinary way would be somewhat difficult. It was obviously desirable that brake operation should be standardised, at any rate in essentials, and in fact certain stipulations were made in their airworthiness requirements. Moreover, pilots were a conservative race and did not always take kindly to new ideas and unaccustomed practices, however desirable in themselves. It happened, however, that just now there must be a large number of pilots who have had to accustom themselves to the common American system of toe-pedal operation and might therefore be able to form a fair opinion of its merits, which he submitted were very great.

Some years ago, when aircraft brakes were in their infancy and were regarded as of doubtful value and even a danger, he had the opportunity of flying a number of different types with various systems of braking, and he formed the definite opinion that operation by toe pedals, with a separate parking lever, was by far the simplest, easiest and most effective method. Unfortunately some specimens of this system were so badly designed that it did not meet general approval, but he had always felt that the fault lay in the application, rather than in the principle itself. At this time, too, rudder bars had not given place to the now almost universal pedals, on which it was much easier to mount a usable brake pedal.

Application of brakes by toe pedals had the advantage that only one kind of motion was required whether they are used for stopping or steering or both at once, instead of two distinct actions as with our system, and this one motion was a natural one, familiar to anyone who had driven a motor car. Steering control can be applied more quickly and sensitively than by using the rudder control, which is often heavy and sluggish on large aircraft, and taxi-ing along a winding track especially in a strong following wind can be exceedingly tiring; whereas with toe pedals the rudder need not be moved and may even be locked, and if the brakes are well designed no great effort was needed. He did not suggest that all American brakes were beyond criticism, but he did most emphatically assert, as a result of considerable experience, that the system, as a system, was vastly superior to ours.

He would urge an early review of the whole question, and would welcome opinions of other pilots with experience of both systems.

Mr. A. R. OGSTON (contributed): A statement was made a few months ago during a discussion following the reading of a paper on " aircraft hydraulics " when the question of the pre-rotation of landing wheels was also raised. The statement was that " it had been found on many occasions that aeroplanes came in to land with the brakes on," since pilots claimed this helped to reduce the landing run.

If such a practice were prevalent—and he thought that this was open to considerable doubt—it would seem that tyre wear would be much increased, while the control of the aircraft on touching down might also be badly affected.

It would be interesting to hear from Mr. Wright whether such a practice was, in fact, indulged in, and if so, what were his views with regard to it?

Mr. H. V. STEVENTON (Gloster Aircraft) (Associate Fellow) (contributed): He was very interested to observe that Messrs. Dunlop favour the use of high pressure tyres up to the order of 90 lb./sq. in., but

he was of the opinion that even this pressure was only an intermediate stage in development of really high pressure equipment. There were a few points which he would like Mr. Wright to answer and elaborate upon.

1. He noticed that no comment had been made in favour of the use of treaded tyres. This type of tyre was in frequent use on American types of aircraft and on some British types. Could Mr. Wright give some reasons for their use and whether the increase in weight of the tyre justifies their use, particularly on the high pressure types?

2. It was a known fact that as take-off speeds of modern aircraft became higher and higher, further problems arose on tyre design. It was known that the tyre increased in diameter as the speed of rotation increased. Could Mr. Wright give some indication of the variation in tyre diameters, say, for a take-off speed equivalent to 125 m.p.h., for nominal tyre sizes of about 30in. diameter and the 111in. diameter tyre which he quoted? It would be useful if his figures quoted nominal diameter, normal grown diameter and expanded diameter when rotating at high speed. This latter figure was important from the point of view of fork clearance and structural clearance in the wing or body when retracted.

3. As a development of the above point, the problem of balancing of wheels was important and was not commented upon in the paper. Perhaps Mr. Wright could give some information on the type of balance he expected to obtain on these large wheels, also if he had any information regarding vibration caused in wings by large wheels rotating and if any serious consideration had been given to the possibility of putting the brakes on automatically during the process of undercarriage retraction.

4. He noted that Mr. Wright made no mention of any other form of braking than the " sac " type. Could he comment on the relative efficiency of the " sac " type compared to the disc types? Which did he think would be the ultimate development for the highly efficient brake systems of the future?

Mr. V. R. BILLING (Associate Fellow) (contributed): The difficulties Mr. Wright mentioned confronting the designer of bigger and better aeroplanes were unfortunately inherent. Wheel weight varied theoretically, as the aircraft all-up weight to the power of 3/2 (for a given tyre pressure) and it was a great tribute to wheel manufacturers that the power of 3/2 is never attained; similarly wheel diameter varied as the square root of the all-up weight (theoretically, but at a lesser rate in practice), while for dynamically similar aircraft the linear dimensions vary only as the cube root of the weight. The figures produced by the lecturer showed that the wheel and tyre designer has responded nobly to the problems imposed upon him.

Was it not time the aircraft designer relieved the wheel and brake designer of part of his burden? An aerodynamic brake, coming into operation at touch-down and capable of reducing the speed from landing speed to half landing speed would alone dissipate 75 per cent. of the forward K.E. at touch-down and safely leave the remainder to the wheel brakes as it was of little use at low speeds. Until the problems of wheel weight, wheel size and brake cooling are reduced, we could not expect bigger and better aeroplanes. The only solution at present was that the customer can have any kind of aeroplane he wants, so long as it was a flying boat!

REPLY TO DISCUSSION

Mr. WRIGHT: Dealing first with the suggested advantage of rotating the wheels immediately before the aeroplane landed, he said he was pleased to have the opportunity of saying to so many aircraft designers and users that, after very careful consideration and experiment, he was satisfied that it really was a complete myth, at any rate for landing speeds under 100 m.p.h. The tread of the aeroplane tyre was not worn seriously

by its impact with even concrete runways; and if there were any advantage in rotating the wheels before landing, it was not worth the trouble and the weight involved in providing the necessary mechanism. Tyres had been carefully weighed after each and repeated landings, and the amount of rubber lost per landing was very small indeed. All of them had seen tyres which had been worn right through to the carcase; invariably that condition was due to the locking of the wheels resulting from the application of the brake too fiercely. Although Mr. Robson had said that it should not be possible to lock the wheel, obviously it was possible to lock the wheel just before the aeroplane placed its full weight on the ground; therefore, it was most desirable that, whatever brake control was used, it should be sufficiently and immediately sensitive to enable a skilled pilot to avoid the locking of the wheel.

With regard to standardisation, none would be more pleased than his Company to be able to standardise. But aeroplanes as such covered a very wide range, from the very small machines weighing a few hundred pounds to those which were envisaged weighing up to 250,000 lbs. Even to-day, with aeroplanes under construction which would weigh 60,000 or 70,000 lbs., or something of that order, there was a tremendous range to cater for in respect of wheels. The problem was further complicated by the fact that, when a wheel and brake were designed for an aeroplane, often some considerable time, even years elapsed, before that aeroplane with that wheel went into production; in the meantime improvements had been effected, so that very often, by the time the aeroplane and wheel were in production, it was possible to use a smaller wheel on that aeroplane than that which was originally designed for it. Thus, whilst it was attractive to standardise and to reduce the number of types of wheels made, the effect of so doing might be to limit the performance of aeroplanes.

In reply to Mr. Conway, he really did not think that the reduction of inflation pressure would greatly increase tyre life; he was quite satisfied that the higher pressure tyres which his Company offered to-day should give a perfectly satisfactory life.

He appreciated that on the smaller higher-performance machines the growth of the tyre was a serious problem; that problem was being studied very carefully, and it might well be that in the near future they would be able to reduce the extent of the growth of the tyre during service. The use of synthetic textiles might be of some advantage in that connection. Rayon, for instance, had been introduced extensively in place of cotton cord for the casing structure of aero covers. The main advantages of the use of that material were increased strength, particularly at the higher running temperatures, improved resistance to concussion bursts and, for equal strength, a weight saving of about 10 per cent. as compared with cotton. Nylon had also been used experimentally. Unfortunately, supplies in this country were very small at present; but the material was much stronger than Rayon and cotton for a given weight, although it introduced a number of other problems in tyre manufacture. However, he hoped it would be possible to be of some assistance to Mr. Davenport in that respect in the comparatively near future.

Dealing with the remarks made concerning the hydraulic braking system, he said he was most sympathetic to the aircraft designer in regard to the desire to reduce the number of services on the aircraft, and he was quite sincere in saying that there was no fundamental difficulty in making the brakes work hydraulically. Brakes of the expander tube and other types were made in large quantities and were operated quite successfully by the existing hydraulic system installed for the undercarriage and other services.

As to the method of brake control, in this country they had used the hand control interconnected with the rudder bar. But so far as the brake itself was concerned, he had no

predilection in favour of that. The decision as to whether hand or foot control was used rested with the designer or the operator of the aircraft. His Company's problem would be very much easier if foot operation by independent pedals for each brake were called for. They had had to exercise great ingenuity in designing suitable controls which could be operated by hand and yet be interconnected with the rudder bar.

Recalling the references made to rigid shoe brakes, he said that whilst his remarks were directed mainly to the higher performance of the larger sizes of brakes, he contended quite seriously that any rigid shoe brake was likely to give trouble, due to the very high temperatures developed by the brake drums. That difficulty could be overcome by doubling the weight of the brake drum and thus reducing the temperature attained; but in aircraft it was always desirable to restrict weight to the minimum, and designers obviously reduced the weight of the brake drum and increased the temperature as much as they dared. He did not think they would ever arrive at a cylindrical drum which would remain sufficiently true at these high temperatures for the rigid shoe brake. He was aware that German brakes were still operated on that principle, but from tests carried out they were satisfied that the inflated "sac" brake was better in that respect, for it could accommodate very serious distortion of the brake drum; and he emphasised that the majority of the larger American aircraft used that type of brake to-day. So far as the disc brake was concerned, he was prepared to qualify his remarks slightly, because there again the method of operation was very often of the inflated "sac" type, which could accommodate itself to distortions of the disc.

He had always used a brake testing machine which did not require the use of a pneumatic tyre, partly for reasons of economy; the large pneumatic tyres were very expensive and they would not stand up to very prolonged running. They believed they could get an equally good brake test by stopping the flywheel without taking the torque through the tyre.

In reply to Major Mayo:—The form of the curve between the $1\frac{1}{2}$ per cent. W. for the 10,000 lb. aeroplane and 3 per cent. W for the 250,000 lb. aeroplane was approximately a straight line. For the larger aeroplane wheel, he would emphasise the desirability of using the multiple wheel arrangement, and it was interesting to note the importance Major Mayo placed on safety of this arrangement.

He agreed with Group-Captain Scroggs that it would be most helpful to have the views of pilots as to the comparative advantakes of hand and foot brakes.

So far as the brake control designer was concerned, the foot pedal method was obviously simpler. There was evidence from Service pilots that hand operation was preferred.

Replying to the points raised by Mr. Steventon, Mr. Wright's opinions were:—

1. The pattern tread tyre was less liable to cut, particularly when landing on prepared runways.

2. Data on the increase of diameter due to the speed of rotation was being prepared, and will be made available.

3. The importance of the balancing of wheels and tyres was appreciated, and whilst the effect of bad balance can be avoided by the operation of the brakes in the main wheels, some difficulty was experienced with the unbraked nose wheel on a tricycle aeroplane.

It would probably be necessary to arrange either for a satisfactory balancing of this wheel and tyre assembly, or, alternatively, as Mr. Steventon suggested, to arrange for the automatic stopping of the wheel in the retracted position.

4. He preferred the inflated sac type of brake.

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

EIGHTIETH ANNUAL REPORT OF THE COUNCIL, 1944-1945

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Honorary Accountant

Mr. A. N. D. Smith, F.C.A.

Secretary

Captain J. Laurence Pritchard, Hon.F.R.Ae.S., Hon.M.I.Ae.S.

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Mr. L. A. Wingfield (Chairman), Mr. G. H. Dowty, Mr. W. C. Devereux, Mr. A. G. Elliott.

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Sir Roy Fedden (Chairman), Dr. H. Roxbee-Cox, Mr. W. C. Devereux, Major R. H. Mayo, Mr. R. K. Pierson.

S.B.A.C. Liaison Committee:

Sir Roy Fedden (Chairman), Mr. A. Gouge, Major F. B. Halford, Sir Oliver Simmonds.

Representatives on Other Bodies

Advisory Committee for Aeronautical Engineering of the City and Guilds of London Institute: Professor F. T. Hill and Captain J. L. Pritchard.

Advisory Council of the Science Museum: Lord Sempill.

Air League of the British Empire: Mr. W. O. Manning and Mr. Griffith Brewer.

Association of Special Libraries and Information Bureaux: Mr. J. E. Hodgson (Hon. Librarian).

British Standards Institution, Aircraft Committee: Major Mayo and Dr. H. C. Watts.

British Standards Institution, Committee on Symbols and Abbreviations Used in Engineering: Dr. H. Roxbee-Cox.

British Standards Institution Technical Committee on Aircraft Nomenclature: Professor L. Bairstow and Captain J. L. Pritchard.

British Standards Institution, Units and Technical Data Committee: Lieut.-Col. W. Lockwood Marsh, Major B. W. Shilson.

Engineering Joint Council: Mr. A. Gouge.

Engineering Joint Council, Special Educational Representative: Professor G. T. R. Hill.

The Guild of Air Pilots and Air Navigators of the British Empire, Sefton Brancker Memorial Fund Committee: Captain P. D. Acland.

Joint Standing Committee with the Society British Aircraft Constructors and the Royal Aero Club: Mr. E. F. Relf, Lord Sempill, Lord Brabazon, Mr. W. C. Devereux, Mr. A. Gouge, Sir Oliver Simmonds and Mr. G. H. Dowty.

National Central Library: Mr. J. E. Hodgson (Honorary Librarian).

Professional Classes Aid Council: Lord Sempill.

Seagrave Memorial Fund Committee: Sir Richard Fairey.

Institution of Mechanical Engineers, National Certificates and Diplomas in Mechanical Engineering: Sir Roy Fedden and Professor F. T Hill.

General Board of the National Physical Laboratory: Mr. Griffith Brewer and Mr. W. C. Devereux.

Membership

The membership of the Society for 1944 shows the substantial increase over 1943 of 1,002 (excluding suspended members).

The membership at the end of 1938 was 2,154, so the increase during the war has been 2,515. The Council have followed the policy of not lowering the standard for the various technical grades and it is expected therefore that there will not follow the decline in membership which followed the last war.

	Members.	Honorary and Life Members.	Suspended Members.	Grand Totals.
Fellows	267 (216)	27 (25)	1 (1)	295 (242)
Associate Fellows ...	1370 (1206)	8 (7)	13 (40)	1391 (1253)
Associates	1033 (740)	5 (5)	13 (32)	1051 (777)
Graduates	479 (369)	— —	13 (11)	492 (380)
Companions	211 (169)	9 (9)	5 (10)	225 (188)
Founder Members ...	15 (16)	1 (1)		16 (17)
Students	1225 (885)	— —	36 (71)	1261 (956)
Temporary Honorary Members	— —	19 (19)	—	19 (19)
Totals	4600 (3601)	69 (66)	81 (165)	4750 (3832)

NOTE. Figures in brackets give the membership as at December, 1943.

Annual General Meeting

The Annual General Meeting was held in the offices of the Society on March 27th, 1944, at 6 p.m.

Present: Mr. A. Gouge (President) in the Chair.

Mr. E. J. Archbold (Graduate)
Mr. Griffith Brewer (Honorary Fellow)
Mr. E. P. Bridgland (Student)
Mr. A. R. Collar (Associate Fellow)
Mr. R. Goldby (Associate Fellow)
Professor F. T. Hill (Fellow)
Mr. J. Vivian Holman (Associate)
Major R. H. Mayo (Fellow)
Captain D. Nicolson (Fellow)
Mr. G. J. Richards (Associate Fellow)
Mr. J. G. Roxburgh (Student)
Major B. W. Shilson (Fellow)
Mr. H. M. Schofield (Associate Fellow)
Mr. G. Stainton (Graduate)
Mr. Lawrence Wingfield (Associate) (Solicitor)
Mr. J. A. C. Williams (Associate Fellow)
In attendance: The Secretary and Miss Barwood.

1. The Secretary read the Notice convening the Meeting as follows:—

ANNUAL GENERAL MEETING

NOTICE IS HEREBY GIVEN that the Annual General Meeting of the Royal Aeronautical Society with which is incorporated the Institution of Aeronautical Engineers will be held on Monday, March 27th, 1944, at 6 p.m., in the offices of the Society, at 4, Hamilton Place, London, W.1.

AGENDA

1. To read the Notice convening the Meeting.
2. To receive and deliberate upon the Report of the Council on the state of the Society and the Balance Sheets of Aerial Science, Ltd., and Aeronautical Trusts, Ltd., for the year ended December 31st, 1943.
3. To receive the nominations for Council for the years 1944-1945.

4. To announce the list of Fellows elected by the Council in accordance with Rule 4.

5. To appoint the Auditors for the ensuing year for Aerial Science, Ltd., and Aeronautical Trusts, Ltd.

6 Any other business.

By Order of the Council,
J. LAURENCE PRITCHARD,
Secretary.

2. The Secretary drew members' attention to the Annual Report on the table which he said was self-explanatory. He mentioned the Endowment Fund which had reached a total of £108,071 8s. 7d. and which would reach the grand total of £120,000 when all the seven-year contributions had been completed.

The adoption of the Report was moved by Major Shilson and seconded by Mr. J. Vivian Holman and passed unanimously.

3. The meeting was then thrown open for general discussion by members.

Captain Nicolson drew attention to a suggestion he put up to the Worshipful Company of Shipwrights who had a scheme for training architects and he had suggested they include aeronautical engineers in their scheme. They awarded three gold medals in a year and he had also suggested they award one for aeronautics. Captain Nicolson said that as the Society appeared to have an educational scheme of their own he would withdraw his suggestion.

The Secretary asked if the Company had a Charter, and if so, did the Charter include training in aeronautical engineering?

Captain Nicolson said he had brought into the Shipwrights' Company many leading aeronautical people, but if the Society were going to have such a large fund it looked as though it could look after its own apprenticeship schemes. He suggested it had been agreed by the Society that Naval Architecture and Aeronautical Engineering were very much akin.

The Secretary said he thought the Society would oppose any scheme whereby the Naval Architects incorporated the training of aeronautical engineering in their programme, and mentioned the existing apprenticeship scheme of the Society of British Aircraft Constructors.

Mr. Wingfield said that if any munificent person wanted to give money for aeronautical training then the proper channel was the Society.

Mr. Gouge said the Council would be very interested to hear more about the scheme and would assist in adjudicating in any prizes that were to be awarded, and suggested the Worshipful Company of Shipwrights be informed the Society would like a representative to discuss the matter with them, say Captain Pritchard.

Arising out of the reports of the Education Meetings, Major Shilson asked if this Society had issued any pamphlets as a guide to parents. The Secretary replied there had not been any published so far.

4. The Secretary reported the following nominations to fill the 10 vacancies on the Council:—E. J. N. Archbold, F. R. Banks, W. C. Devereux, G. H. Dowty, A. G. Elliott, F. B. Halford, N. S. Muir, R. K. Pierson, B. W. Shilson, C. C. Walker.

5. The Secretary read the names of those proposed for Fellowship and passed by the Council. Under the new rules these are announced at the Annual General Meeting each year.

Ralph Harrison Archbald
Ernest Leon Bass
Ivor Bowen
Francis B. Bradfield
Harry Cantrill
Roland Henry Chaplin
Arthur Roderick Collar
Hayne Constant
Philip Andrew Cooke
Lawrence Percival Coombes
Harold Leslie Cox
Graham Richards Dawbarn
Hugh Latimer Dryden
Hugh Arthur Francis
Ernest Turner Jones

Roy Patterson Key
Robert Lang Lickley
Claude Percival Thomas Lipscomb
Benny Lockspeiser
John W. Maccoll
John Francis Xavier Mckenna
Harry Lawley Milner
John Lankester Parker
William George Arthur Perring
William Edward Willoughby Petter
William Eliezer Prytherch
Alfred Grenvile Pugsley
John Edwin Ramsbottom
Julius Ratzersdorfer
Seymour Cunningham Redshaw
Andrew Alexander Ross
Arthur Alexander Rubbra
Trevor Prince Searight
Leonard Frederick George Simmons
Tom Roberts Thomas
Oliver Thornycroft
Ernest John Dennis Townsend
Cyril Frank Uwins
Herbert Frank Winny
Stephen Joseph Zand

6. Mr. J. A. C. Williams (Associate Fellow) said the Journal at the moment had quite an appreciable amount of its available paper supply devoted to advertisements, and in view of the scarcity of paper he would suggest the Society adopt the scheme of the Institute of the Aeronautical Sciences where advertisers paid a certain sum of money and just had their names and addresses printed in a list in the front of the Institute's Journal.

The Secretary said he would like to publish more technical articles, but they were just not available.

Mr. Gouge said there was something in Mr. Williams' suggestion and thought half the advertisement space might be saved by adopting the scheme.

Mr. Williams said he had looked through the Journals for the past year and found 60 pages devoted to translations already available through the S.B.A.C. He asked if an appeal could be made to the industry for technical papers and if we could reprint some articles from the American technical press.

The Secretary mentioned that the Abstracts and Notices were printed at the special request of R.T.P.3.

Mr. Williams suggested that a small committee be formed to go through the American publications each month to select articles for reprinting.

The Secretary said he already did that himself, but most of the articles were too long to reprint in the Journal.

7. Mr. Holman (Associate) asked if the Society could give some standing to those Schools setting out to teach aeronautical engineering. There would be many people coming out of the Services who would need guidance and it would help them if the Society could vet the various schools in some way.

The Secretary replied that some years ago the Society was approached by various correspondence schools asking if the Society would recognise their Diplomas. The Society replied that if the schools were prepared to have their courses vetted by the Society's Examiners then they would give an opinion as to whether those courses were suitable for the Society's Associate Fellowship Examinations. Two of the schools conformed to this suggestion and as a result have trained successful candidates.

Professor F. T. Hill (Fellow) said it would be dangerous for the Society to go any further than that as the schools were run for commercial ends and would seize on any recommendation by the Society for advertising purposes.

The Secretary mentioned that any literature or advertising matter issued by these schools were vetted by the Society and when prospective candidates asked the Society to recommend a correspondence school these two were quoted, but that under the Rules we were not allowed to recommend any particular school, although they had in the

past trained successful candidates for our examinations.

Mr. Williams asked what the procedure was with regard to schools like the de Havilland School and the Chelsea College of Aeronautical Engineering. The Secretary replied that in the case of the de Havilland School the papers and answers were submitted to the Society's examiners for vetting and marking and that students of the Chelsea College took the Examinations at the end of their training.

Captain Nicolson asked if the programme of A.T.C. boys was influenced by the Society. They wanted to enlarge their knowledge, but seemed to have no opportunity to go beyond the elementary stage. Mr. Williams said the answer to that was that A.T.C. Squadrons did not have time for anything but the most elementary work.

Major Mayo proposed a very hearty vote of thanks to the Chairman, which the meeting accorded with acclamation.

Donations

The Council have to thank the Society of British Aircraft Constructors for the twentieth year for their grant of £250 to the Funds of the Society.

The Endowment Fund last year reached £108,071, and this year the total is £119,820 19s. 0d.

The rapid growth of the Endowment Fund during the last seven years has largely been due to the many generous gifts from firms in the industry and individuals. In the report of the Council for 1939-40 an account was given of the initiation of the Fund and its history, and acknowledgments were made in the Journal for October, 1939, of the seven year gifts which were being received.

Special General Meeting

A Special General Meeting of members was held in the offices of the Society on Saturday, February 5th, 1944, at 3 p.m.

Present: Mr. Griffith Brewer (Past-President) in the Chair.

E. J. Archbold (Graduate)
A. C. Chorlton (Companion)
M. J. B. Davy (Fellow)
E. C. Gordon-England (Fellow)
D. J. Gribbon (Associate Fellow)
G. W. Frankland (Associate)
J. Vivian Holman (Associate)
S. Scott-Hall (Associate Fellow)
J. Kenny (Associate Fellow)
P. Kubicki (Associate Fellow)
F. W. Merriam (Fellow)
N. Nicholas (Fellow)
E. Percival (Fellow)
N. H. Netell (Associate)
W. S. Jones (Graduate)
A. G. Horndrow (Associate)
J. S. Murray (Associate)
F. McHarry (Companion)
H. Scowen (Associate)
B. W. Shilson (Fellow)
Mrs. Walker-Sinclair (Companion)
H. Radlett (Associate Fellow)
F. G. Wade (Associate)
H. Wernecki (Associate Fellow)
J. A. C. Williams (Associate Fellow)
H. T. Winter (Founder Member)
P. W. Wreford-Bush (Student)
W. T. Wakeham (Associate Fellow)
H. M. Yeatman (Associate Fellow)

In attendance: The Secretary and Miss Barwood.

1. The Secretary read the Notice convening the meeting as follows:—

"NOTICE IS HEREBY GIVEN that a Special General Meeting under Rules 100 and 101 of the Royal Aeronautical Society with which is incorporated the Institution of Aeronautical Engineers will be held on Saturday, February 5th, 1944, at 3 p.m., in the offices of the Society, 4, Hamilton Place, London, W.1, to consider alterations and additions to the Rules."

Mr. Gordon-England formally moved and Mr. N. Nicholas seconded the adoption of the amended Rules. The motion was

unanimously carried. The amended rules were as follows:—

Rule 5.—Nomination (on Form A) for Fellowship must be received by March 1st each year at the latest, for consideration at the March Council Meeting.

Rule 35 (*b*).—The proposal form for a Fellow must be signed by at least four Fellows, none of whom may be a member of Council or of the Grading Committee of Council, and the Candidate must sign the undertaking appended to the form.

Rule 35 (*c*).—The proposal form for an Associate Fellow must be signed by at least four Fellows or Associate Fellows, of whom two at least must be Fellows, and none may be a member of Council or of the Grading Committee of Council. The Candidate must sign the undertaking appended to the form.

The proposal form of an Associate Fellow under Rule 17 must be signed by four Fellows, none of whom shall be a member of Council or of the Grading Committee of Council.

Rule 61.—The number of members of Council shall be twenty-four, inclusive of the President and one or more (not exceeding four) Vice-Presidents and the three immediate Past-Presidents.

Rule 72 (*a*).—Not less than sixteen shall be elected from the technical or scientific grades of the R.Ae.S., that is to say, from among the Fellows, Associate Fellows and Associates.

FORM A

FELLOWSHIP NOMINATION

WE, THE UNDERSIGNED Fellows of the Royal Aeronautical Society, with which is incorporated the Institution of Aeronautical Engineers, recommend

.....

from PERSONAL KNOWLEDGE, as in every respect being worthy of election to Fellow, because

.....

(Here the qualifications of the Candidate, according to the spirit of Rules 3-6 inclusive of the Rules should be distinctly specified.)

(Signed) ..... (Fellow)

..... (Fellow)

..... (Fellow)

..... (Fellow)

I, THE UNDERSIGNED, being upwards of 28 years of age, do hereby promise that, in the event of my election, I will be governed by the Rules of the R.Ae.S., as they are now formed, or as they may be hereafter altered, amended or enlarged, under the powers of the said Rules; and that I will promote the objects of the R.Ae.S. as far as may be in my power.

(Signed) .....

The Council, having considered the above recommendation, recommend that A.B. shall be accepted as a Fellow of the R.Ae.S.

(Signed) ..... (Chairman)

Dated this ..... day of ..... 19..

Note.—This form may not be signed by any member of Council or of the Grading Committee of Council.

President

Sir A. H. Roy Fedden, M.B.E., M.I.A.E., M.S.A.E., D. Sc., Hon. F. S. A. W. E., F.R.Ae.S., was elected President of the Society for the year October, 1944, to September, 1945.

Vice-Presidents

The following were elected Vice-Presidents of the Society for the year 1944-1945:—

Mr. W. C. Devereux, F.R.Ae.S.

Mr. R. K. Pierson, C.B.E., B.Sc., F.R.Ae.S., A.M.Inst.C.E.

Medals and Awards

During the year the Council made the award of the Gold Medal of the Society to Air Commodore F. Whittle, C.B.E., B.A., F.R.Ae.S., for his work on Jet Propulsion.

This is the highest award the Society can bestow.

The Elliott Memorial Prize and the Major Baden-Powell Memorial Prize were awarded as follows:—

Elliott Memorial Prize—Aircraft Apprentice H. C. Hughes.

Baden-Powell Memorial Prize—Franz Julius Wallach; Charles Neville Jones.

(Awarded to the best student in the May and December Associate Fellowship Examinations.)

Honours

The following members were recipients of Honours during the year:—

Knights Batchelor—J. S. Buchanan, C.B.E., A.M.I.M.E., F.R.Ae.S.; Air Commodore J. A. Chamier, C.B., C.M.G., D.S.O., O.B.E., A.F.R.Ae.S.

K.C.B. (Military Division)—Air Marshal R. S. Sorley, C.B., O.B.E., D.S.C., D.F.C., A.F.R.Ae.S.

C.B. (Military Division)—Air Vice Marshal D. C. T. Bennett, C.B.E., D.S.O., F.R.Ae.S.; Air Vice Marshal E. W. Stedman, O.B.E., A.R.C.Sc., Wh.Sc., F.R.Ae.S.

C.B. (Civil Division)—Air Commodore V. S. Brown, O.B.E., M.A., F.R.Ae.S.

C.B.E. (Civil Division)—E. F. Relf, F.R.S., A.R.C.Sc., F.R.Ae.S.

M.B.E. (Civil Division)—C. H. Cunniffe; Squadron Leader J. D. Haddon, F.R.Ae.S.; F. J. V. Holmes, A.F.R.Ae.S.

O.B.E. (Civil Division)—Dr. A. G. Pugsley, F.R.Ae.S.

Society of British Aircraft Constructors' Scholarships

The Scholarship Selection Committee of the Society of British Aircraft Constructors and the Royal Aeronautical Society have made awards of Society of British Aircraft Constructors' Scholarships to the following:

4th September, 1944.

The Nigel Norman Scholarship—A. R. W. Denison.

The John de Havilland Scholarship—D. Gill.

And Scholarships to R. G. Harmer, E. Islip, K. A. Major, J. F. Martin, W. R. Stirling, P. Wainwright, A. F. A. Watts.

15th December, 1944.

A. P. Chalk, J. B. Chaplin, R. J. Frost, R. G. Hinckley, A. W. Kitchenside, R. J. Margetts, A. Whitehead-Hodges.

Wilbur Wright Memorial Lecture

The 32nd Wilbur Wright Memorial Lecture was delivered by Sir A. H. Roy Fedden, M.B.E., M.I.A.E., M.S.A.E., D.Sc., Hon.F.S.A.W.E., F.R.Ae.S., entitled "Aircraft Power Plant—Past and Future." A full report of the lecture was published in the Journals of the Society for September and October, 1944.

Branches

The Council are glad to record that during the year there has been a considerable revival in the activities of the Branches. During the year three new Branches have been formed at Birmingham, Derby and Glasgow.

A special Branches Committee of the Council, under the Chairmanship of Major Shilson, has been formed and as a result of a questionnaire sent out by the Committee and a meeting of Secretaries and Chairmen of the Branches at headquarters, many suggestions have been put forward for linking the Branches more closely with headquarters and increasing the value of the excellent work they have been doing. Membership of the Branches now is nearly 5,000. A complete list of Branches is published at intervals in the Journal.

British Empire Lecture

The Council of the Royal Aeronautical Society have completed during the year arrangements for the founding of a British Empire Lecture.

The lecture, on any aeronautical subject approved by the Council, will be delivered annually in September in London, by a

lecturer, chosen in alternate years from the British Dominions, India and Colonies and Great Britain.

The Council, by founding this British Empire Lecture, are anxious to encourage new ideas and new points of view from all parts of the British Empire, and to make the Lecture second only in importance to the Wilbur Wright Memorial Lecture.

The British Empire Lecture will have a premium of £50 attached to it, and in the case of lecturers coming from the Dominions and Colonies an allowance up to £100 will be paid towards the Lecturer's expenses.

It is proposed to hold the first lecture in September, 1945, and suggestions for lecturers should be received by May 31st, 1945, at the latest.

Lectures

The following lectures were arranged during the year:—

February 10th, 1944—"Flight Testing Methods," by Mr. E. T. Jones, M.Eng., A.F.R.Ae.S.

February 24th, 1944—"Structural Features of German Aircraft," by Dr. D. M. A. Leggett, Ph.D., A.F.R.Ae.S., and Mr. H. Davison.

March 9th, 1944—"Aerodynamic Features of German Aircraft," by Mr. M. B. Morgan, M.A., A.F.R.Ae.S., and Mr. R. Smelt, B.A.

November 4th, 1944—Informal Discussion on Civil Aviation—Lord Brabazon of Tara, M.C., P.C., F.R.Ae.S., in the Chair.

January 22nd, 1944—"Aspects of the Design and Production of Airframes with particular reference to their co-ordination and to the reduction of the development period," by Mr. E. Mensforth, M.A., M.I.M.E., and Mr. W. E. W. Petter, B.A., F.R.Ae.S.

Premium Awards

The Council have set aside an annual sum of £250 for the payment of premium awards to the authors of papers published in the Journal, and it is hoped that members will be encouraged to submit any papers they have written, to the Journal in the first place.

Graduates' and Students' Section

Eighth Annual Report of the Graduate and Student Section

Summary

During the year the Section has held seven technical meetings attended by two hundred and sixty members and visitors. A meeting was held at the works of the Airscrew Company, which included a visit to the Company's wind tunnel and a film show. The Section has once again held its Annual Informal Dinner.

Management

The affairs of the Section have been managed during this session by a Committee consisting of the following members:—

Mr. P. L. Cronbach (Graduate), Chairman.
Mr. R. T. Wall (Graduate), Vice-Chairman.
Mr. D. Whaley (Graduate).
Mr. G. Roxburgh (Graduate).
Mr. P. H. Wall (Graduate).
Mr. G. H. Forster (Graduate).
Lieutenant (A) F. V. K. Sutton, R.N.V.R. (Graduate).
Mr. B. C. Smith (Student).
Mr. M. J. Mott (Student).
Dr. W. C. J. Garrard (Student).
Mr. E. J. N. Archbold (Graduate), Secretary.
Mr. J. W. F. Housego (Graduate), Asst. Secretary.

Activities

1. *Technical Meetings*

The Section has held the following technical meetings during the session:—

6th April, 1944—Mr. P. G. Masefield, A.F.R.Ae.S.—American Aircraft.

19th April, 1944—Mr. A. J. Penn—Design and Operation of Superchargers.

11th May, 1944—Mr. J. A. Churchill—Power Plant Installations and Design.

1st June, 1944—Mr. B. G. Markham, M.A., A.F.R.Ae.S.—Possible Developments in the Design of Air-Cooled Engines.

24th July, 1944—Mr. P. L. Coombes, F.R.Ae.S.—Aeronautical Developments in Australia.

6th September, 1944—Mr. W. S. Hemp, A.F.R.Ae.S.—Some Dynamical Problems in the Design of Large Aircraft.

4th October, 1944—Squadron Leader Stewart—Some Physiological Aspects of Flying.

2. *Other Meetings*

On Sunday, 29th October, 1944, at the invitation of the Chairman of the Airscrew Company, Mr. J. D. Titler, the Section paid a visit to the Company's premises at Weybridge. During the visit, Mr. J. A. C. Williams, A.F.R.Ae.S., Chief Technical Assistant, read a paper on "The Design of Axial Flow Fans." After tea in the canteen, the Company's fan testing plastic wind tunnel was visited and the meeting closed with a showing of aeronautical films.

3. *Annual Informal Dinner*

Sir A. H. Roy Fedden, F.R.Ae.S., President, was the guest of the Section at its Annual Informal Dinner, held this year at Gunter's Restaurant, on Friday, 15th December, 1944.

Group Representation

The Committee has commenced the task of setting up a Group Representation scheme and a number of Group Representatives have have been appointed.

The first questionnaire on the affairs of the Section has already been circulated to representatives.

Appointments Register

The Committee has asked the Council to consider the setting up of an Appointments Register for members of the Society and has addressed a memorandum to the President on the subject.

Acknowledgments

The Section wishes to record its indebtedness to Captain Pritchard and the staff of the Society, for their continued invaluable assistance and encouragement. It also wishes to extend its grateful thanks to those gentlemen who have read papers during the session, and particularly to Mr. J. D. Titler and others of the Airscrew Company, for their kindness and hospitality towards the Section.

Associate Fellowship Examinations

The results of the Associate Fellowship Examinations held in May and December, 1944, were published in the Journal for August, 1944, and March, 1945. There is again a marked increase in the numbers of candidates taking the examination, both in this country and various centres abroad. The Council view this increase with satisfaction, particularly in view of the difficulties created by the war.

Arrangements were made for the Society's examinations to be held in Prisoner of War Camps, on board ship and at Royal Air Force Stations.

Acknowledgments

The Council gratefully acknowledge the gifts of books, photographs, historical papers and lantern slides from members during the year. All gifts have been acknowledged as received, in the Monthly Notices of the Journal.

Honorary Fellowship

The Council elected the Prime Minister, the Rt. Hon. Mr. Winston Churchill an Honorary Fellow of the Society on his 70th birthday—21st December, 1944.

Finance

The Income and Expenditure Accounts and Balance Sheets of Aerial Science Ltd., and Aeronautical Trusts Ltd., for 1944 are published in the Journal with this report.

The Income and Expenditure Account of Aerial Science Ltd., shows an excess of expenditure over income for the year of £900 18s. 3d., against an excess of expenditure over income for the year 1943 of £302 19s. 3d.

Journal

Increasing paper and labour costs during the year show their effect in the Journal account. A gratifying feature of the accounts, however, is the increased revenue due to sales. During the year a Journal Committee was appointed under the Chairmanship of Mr. G. H. Dowty, and a new form of Journal was decided upon. The advertising revenue for the year 1945 will be greatly increased and there is every prospect that the Journal will show a substantial profit. The Council wish to place on record the great debt the Society owe to the work of the Journal Committee and in particular to Mr. Dowty for their unremitting efforts to produce the Journal in its new form.

INCOME AND EXPENDITURE ACCOUNT OF THE JOURNAL.

Figures in brackets are corresponding figures for 1943.

	£	s.	d.	£	s.	d.
Printing Costs ...	4789	9	11	(3740	13	9)
Special Publications	500	0	0	(750	0	0)
Postages... ...	456	2	1	(340	5	5)
Other Charges ...	499	0	7	(350	16	0)
	£6244	12	7	(£5181	15	2)

	£	s.	d.	£	s.	d.
Sales	2081	3	1	(1551	7	7)
Advertisement Revenue ...	3064	19	3	(3040	0	2)
Excess of Expenditure over Receipts	1098	10	3	(590	7	5)
	£6244	12	7	(£5181	15	2)

Officers and Committees of the Society

The Council wish to place on record their appreciation of the work which has been carried out by the Honorary Officers of the Society during the year.

Captain A. G. Lamplugh, F.R.Ae.S., the Honorary Treasurer, has given invaluable advice and help on financial matters.

Mr. A. N. D. Smith, as Honorary Accountant, has continued to advise the Society, particularly on the difficult problems of income tax which have arisen.

Mr. J. E. Hodgson, Honorary Librarian for so many years, has again during the year 1944 continued to advise the Society on all matters pertaining to the Library.

The Council wish particularly to place on record their appreciation of the work of the various Committees. Much of the work being carried out by certain of the Committees has involved many meetings during the year and the results which they have achieved will prove of very great value to the Society.

Obituaries

S. T. G. Andrews (Fellow), F/O. J. L. Bennett (Associate), *Cpl. G. P. Bridger (Student), *Air Cmdre. D. H. de Burgh (Associate Fellow), Brig. Gen. W. B. Caddell (Fellow), C. V. Coates (Associate Fellow), *Sgt. G. H. Conisbee (Student), *C. H. Crosbie (Graduate), A. Duckham (Companion), W. Villa Gilbert (Fellow), Dr. W. H. Hatfield (Fellow), *A.C.2 J. C. Hornby (Associate Fellow), *F/O. A. M. H. Lewin (Student), *G/Capt. J. F. X. McKenna (Fellow), F/Sgt. J. McTaggart (Student), T. P. Mills (Companion), Lt.-Col. H. W. S. Outram (Fellow), P. Pritchard (Fellow), Air Cmdre. D. Le G. Pitcher (Associate Fellow), *W/Cmdr. C. W. Poulter (Associate), *S/Ldr. J. B. Sayers (Associate), *S/Plt. G. F. Simpkin (Student), F. R. Simms (Fellow), *Lieut. Cmdr. the Hon. J. M. Southwell (Associate Fellow), Dr. J. F. Spong (Founder Member), *R. R. Tant (Associate Fellow), N. R. H. Thompson (Student), Dr. T. Swinden (Fellow), *J. A. C. Warren (Associate Fellow), *F/Lt. A. Whitten-Brown (Student), *B. Wilson (Student).

* Killed on War Service or by Enemy Action.

THE ROYAL

(Aerial

Balance Sheet,

	£ s. d.	£ s. d.
Share Capital—		
Authorised—		
20 Shares of 1/- each	1 0 0	
999 Shares of £1 each	999 0 0	
	1000 0 0	
Issued—19 Shares of 1/- each, fully paid...		19 0
Sundry Creditors		3289 19 11
Amount due to Aeronautical Trusts, Ltd.—		
Royal Aeronautical Society Endowment Fund		234 18 0
Subscriptions and Other Amounts Received in Advance		1157 0 0
Staff Pension Fund		3810 7 3
Income and Expenditure Account—		
Balance at 31st December, 1943	3477 16 1	
Less—Excess of Expenditure over Income for year to date ...	900 18 3	2576 17 10
		£11070 2 0

We report to the Members that we have examined the above Balance Sheet with the Books are of opinion that the Balance Sheet is properly drawn up so as to exhibit a true and correct information and the explanations given to us and as shown by the Books of the Society.

5, Frederick's Place, Old Jewry, London, E.C.2.
23rd March, 1945.

Income and Expenditure Account

	£ s. d.	£ s. d.	£ s. d.
			1943 Figures.
To Establishment Expenses—			
Ground Rent, Heating, Lighting and Insurance		1479 11 7	(1482 14 1)
,, Office and Staff Expenses—			
Salaries	2795 14 1		(2526 9 3)
Printing and Stationery	765 18 7		(622 17 5)
Postages and Telephone	504 2 7		(401 17 0)
Other Charges	1269 6 11	5335 2 2	(955 12 10)
			(4506 16 6)
,, JOURNAL and Sundry Publications—			
Printing Costs	4789 9 11		(3740 13 9)
Special Publications	500 0 0		(750 0 0)
Postages	456 2 1		(340 5 5)
Other Charges	499 0 7		(350 16 0)
	6244 12 7		(5181 15 2)
Less—Sales 2081 3 1			(1551 7 7)
Advertisement Revenue 3064 19 3	5146 2 4	1098 10 3	(3040 0 2)
			(590 7 5)
,, Meetings	... ...	183 13 6	(36 0 10)
,, Library Expenses	... ...	469 15 2	(361 18 0)
,, Prizes and Donations	... ...	5 5 0	(5 5 0)
,, Legal and Professional Charges	... ...	118 13 0	(76 13 0)
,, Staff Pension Fund	... ...	1000 0 0	(500 0 0)
		£9690 10 8	

AERONAUTICAL SOCIETY

Science Limited)

31st December, 1944.

	£ s. d.	£ s. d
Printed Books, Bindings, Old Prints, etc., at cost, less amounts written off		50 0 0
Stock of JOURNALS *and other Publications*		1 0 0
Investment in Subsidiary Company—		
Aeronautical Trusts Limited—		
21 Shares of 1/- each, fully paid, at cost		1 1 0
Staff Pension Fund—		
Investments at cost—£2335 10s. 7d. 2½ % Funding Loan, 1956/61	2201 4 2	
£550 0s. 0d. 3 % Savings Bonds, 1960/70	550 0 0	
	2751 4 2	
Cash at Bank	60 8 1	
Amount due from General Funds...	998 15 0	3810 7 3
Investment at Cost—		
£4000 0s. 0d. 3 % Savings Bonds, 1960/70	... ...	4000 0 0
Sundry Debtors	... ...	2608 13 4
Rent paid in advance	... ..	106 5 0
Cash at Bank and in Hand	... ...	492 15 5
		£11070 2 0

of the Society, and have obtained all the information and explanations we have required. We view of the state of the Society's affairs as at 31st December, 1944, according to the best of our

(Signed) PRICE, WATERHOUSE & CO

for the Year ending 31st December, 1944.

	£ s. d.	£ s. d.	£ s. d. 1943 Figures
By Annual Subscriptions	... ...	8409 12 6	(6806 3 3)
,, Donation	... ...	250 0 0	(250 0 0)
,, Interest on Investment (*less* Tax)...	... ...	60 0 0	(28 15 4)
,, Examinations—			
Fees Received	396 7 0		(436 19 0)
Less Expenses	326 7 1	69 19 11	(265 2 0)
			(171 17 0)
,, Balance, being Excess of Expenditure over Income for year carried to Balance Sheet	... ...	900 18 3	Excess of Expenditure over Income (302 19 3)
		£9690 10 8	

AERONAUTICAL

Balance Sheet,

	£ s. d.	£ s. d.	£ s. d.
Share Capital—			
Authorised—40 Shares of 1/- each		2 0 0	
Issued—21 Shares of 1/- each fully paid			1 1 0
Royal Aeronautical Society Endowment Fund—			
Capital Account—Balance at 31st December, 1943 ...		104434 11 8	
Add Donations received during year		8151 1 7	
Entrance Fees received during year		1267 6 0	
Profit on Sale of Investment...		168 3 0	
		114021 2 3	
Income Account—Balance at 31st December, 1943 ...	3636 16 11		
Add—Surplus of Income over Expenditure for year to date	2163 0 4	5799 17 3	119820 19 6
Pilcher Memorial Fund—			
Capital Account—As at 31st December, 1943		99 14 0	
Income Account—Balance at 31st December, 1943 ...	47 9 8		
Add Income for year to date	4 0 8	51 10 4	151 4 4
Usborne Memorial Fund—			
Capital Account—As at 31st December, 1943		109 2 5	
Income Account—Balance at 31st December, 1943 ...	64 3 0		
Add—Income for year to date	3 19 0	68 2 0	177 4 5
Herbert Ahroyd Stuart Fund—			
Capital Account—As at 31st December, 1943		688 19 0	
Income Account—Balance at 31st December, 1943 ...	363 9 5		
Add Income for year to date	31 8 0	394 17 5	1083 16 5
R.38 Memorial Fund—			
Capital Account—As at 31st December, 1943		978 3 10	
Income Account—Balance at 31st December, 1943 ...	613 17 1		
Add Income for year to date	47 3 10	661 0 11	1639 4 9
Edward Busk Memorial Fund—			
Capital Account—As at 31st December, 1943		449 6 1	
Income Account—Balance at 31st December, 1943 ...	160 17 11		
Add Income for year to date	19 14 0	180 11 11	629 18 0
Wilbur Wright Memorial Fund—			
Capital Account—Balance at 31st December, 1943 ...		1671 8 9	
Add Donations received during year		164 17 6	
		1836 6 3	
Income Account—Balance at 31st December, 1943 ...	159 19 11		
Add Surplus of Income over Expenditure for year to date	16 5 2	176 5 1	2012 11 4
Simms Gold Medal Fund—			
Capital Account—As at 31st December, 1943		524 15 9	
Income Account—Balance at 31st December, 1943 ...	2 18 9		
Add—Income for year to date	15 0 0	17 18 9	542 14 6
Alston Memorial Fund—			
Capital Account—As at 31st December, 1943		245 6 0	
Income Account—Balance at 31st December, 1943 ...	22 14 7		
Add—Income for year to date	7 11 6	30 6 1	275 12 1
			£126334 6 4

We report to the Members of Aeronautical Trusts Limited, that we have examined the above
explanations we have required. We are of opinion that the Balance Sheet is properly drawn up
December, 1944, according to the best of our information and the explanations given to us and as

3, Frederick's Place, Old Jewry, London, E.C.2.
23rd March, 1945.

TRUSTS LIMITED

31st December, 1944.

	£	s.	d.	£	s.	d.	£	s.	d.
Cash in Hand							1	1	0
Royal Aeronautical Society Endowment Fund—									
Leasehold Property at Cost—Less amounts written off									
4, 8, and 9, Hamilton Place				9215	0	0			
Furniture at cost, *less* depreciation				3099	7	6			
Investments at Cost –									
£6474 11s. 7d. 3½ % Conversion Stock	6192	5	1						
£4500 3 % War Loan, 1955/59	4497	0	2						
£15103 15s. 3d. 3½ % War Loan	14000	0	0						
£1000 3 % Defence Bonds	1000	0	0						
£34667 7s. 0d. 3 % Savings Bonds, 1955/65	34708	11	3						
£25000 3 % Savings Bonds, 1960/70	25000	0	0						
£7000 3 % Savings Bonds, 1965/75	7000	0	0						
£629 16s. 4d. London County Council 2¾ % Stock, 1960/70	600	0	0						
£2367 12s. 7d. Manchester 3 % Redeemable Stock, 1952/55	2388	12	11						
£4100 L.N.E. Rly. 3 % Debenture Stock	3162	6	3						
£3100 L.M.S. Rly. 4 % Debenture Stock	3162	19	9	101711	15	5			
Cash at Bank				682	4	9			
Amounts due for refund of Income Tax, etc.				4881	17	10			
Amount due from Aerial Science Limited				234	18	0			
				119825	3	6			
Less—Amount owing for Legal Charges				4	4	0	119820	19	6
Pilcher Memorial Fund—									
£115 6s. 10d. 3½ % War Loan at cost				116	5	0			
Cash at Bank				34	19	4	151	4	4
Usborne Memorial Fund—									
£113 3½ % War Loan at cost				114	11	1			
Cash at Bank				62	13	4	177	4	5
Herbert Akroyd Stuart Fund—									
£683 1s. 0d. 3½ % War Loan at cost				698	19	0			
£250 3 % Defence Bonds at cost				250	0	0			
				948	19	0			
Cash at Bank				134	17	5	1083	16	5
R.38 Memorial Fund—									
£1048 11s. 2d. 3½ % War Loan at cost				1098	18	10			
£350 3 % Defence Bonds at cost				350	0	0			
				1448	18	10			
Cash at Bank				190	5	11	1639	4	9
Edward Busk Memorial Fund—									
£284 4s. 2d. 3½ % War Loan at cost				284	4	2			
£217 London Transport 4½ % "A" Stock, at cost				199	4	6			
				483	8	8			
Cash at Bank				141	11	10			
Amount due for refund of Income Tax				4	17	6	629	18	0
Wilbur Wright Memorial Fund—									
£1246 18s. 1d. 3½ % Conversion Stock, at cost				1000	0	0			
£530 2½ % National War Bonds, 1945/47, at cost				530	0	0			
£250 3 % Savings Bonds, 1960/70, at cost				250	0	0			
£165 3 % Savings Bonds, 1965/75 at cost				165	0	0			
				1945	0	0			
Cash at Bank				65	13	10			
Amount due for refund of Income Tax				1	17	6	2012	11	4
Simms Gold Medal Fund—									
£300 3% Defence Bonds, at cost				300	0	0			
£200 3 % Savings Bonds, 1960/70, at cost				200	0	0			
				500	0	0			
Cash at Bank				42	14	6	542	14	6
Alston Memorial Fund—									
£252 14s. 10d. 3 % War Loan 1955/59 at cost				250	0	0			
Cash at Bank				21	16	5			
Amount due for refund of Income Tax				3	15	8	275	12	1
							£126334	6	4

Balance Sheet with the books of the Company and have obtained all the information and so as to exhibit a true and correct view of the state of the Company's affairs as at 31st shown by the books of the Company.

(Signed) PRICE, WATERHOUSE & CO.

AERONAUTICAL

INCOME & EXPENDITURE ACCOUNTS

Royal Aeronautical Society

	£	s.	d.
To Legal Charges	4	4	0
,, Amortisation of Leasehold Property	485	0	0
,, Depreciation of Furniture	213	15	0
,, Surplus of Income over Expenditure for year carried to Balance Sheet	2163	0	4
	£2865	19	4

Pilcher

To Income for year carried to Balance Sheet	4	0	8
	£4	0	8

Usborne

To Income for year carried to Balance Sheet	3	19	0
	£3	19	0

Herbert Akroyd

To Income for year carried to Balance Sheet	31	8	0
	£31	8	0

R.38

To Income for year carried to Balance Sheet	47	3	10
	£47	3	10

Edward Busk

To Income for year carried to Balance Sheet	19	14	0
	£19	14	0

Wilbur Wright

To 1944 Award	50	0	0
,, Surplus of Income over Expenditure for year carried to Balance Sheet	16	5	2
	£66	5	2

Simms Gold

To Income for year carried to Balance Sheet	15	0	0
	£15	0	0

Alston

To Income for year carried to Balance Sheet	7	11	6
	£7	11	6

TRUSTS LIMITED

FOR THE YEAR ENDED 31st DECEMBER, 1944.

Endowment Fund.

	£ s. d.
By Interest on Investments (gross)	2061 8 5
,, ,, ,, ,, (*less* Tax)...	404 15 7
,, Refund of Income Tax	399 15 4
	£2865 19 4

Memorial Fund.

By Interest on Investments (gross)	4 0 8
	£4 0 8

Memorial Fund.

By Interest on Investments (gross)	3 19 0
	£3 19 0

Stuart Fund.

By Interest on Investments (gross)	31 8 0
	£31 8 0

Memorial Fund.

By Interest on Investments (gross)	47 3 10
	£47 3 10

Memorial Fund.

By Interest on Investments (gross)	9 18 10
,, ,, ,, ,, (*less* Tax)	4 17 8
,, Refund of Income Tax	4 17 6
	£19 14 0

Memorial Fund.

By Interest on Investments (gross)	64 7 8
,, Refund of Income Tax	1 17 6
	£66 5 2

Medal Fund.

By Interest on Investments (gross)	15 0 0
	£15 0 0

Memorial Fund.

By Interest on Investments (*less* Tax)...	3 15 10
,, Refund of Income Tax	3 15 8
	£7 11 6

DEBATE ON CIVIL AVIATION

THE second of a series of debates on Civil Aviation, arranged by the Royal Aeronautical Society, was held in the Lecture Hall of the Institution of Mechanical Engineers at Storey's Gate, St. James's Park, Westminster, London, S.W.1, on Tuesday, March 13th, 1945.

In the Chair: Sir Roy Fedden, F.R.Ae.S. (President of the Society).

The motion for debate was as follows:—

"That, in the opinion of this meeting, speed in air transport is more important than comfort."

THE PRESIDENT: These series of debates were in the nature of an experiment, arranged by the Council of the Society as being a good thing in the interests of civil aviation. The Council believed that the European war would be over this year, and it was felt to be the duty of the Society to take as bold and as progressive a part as it could in regard to some of the vital questions concerning civil aviation and to ventilate them by debate.

In order to present a good cross-section of opinion, some speakers had been asked to support the motion before the meeting and others had been asked to oppose it. The views they would express did not necessarily represent their professional views. There were visitors as well as members of the Society present at the meeting, and the vote which would be taken at the end of the debate would represent just the opinion of those present and did not necessarily reflect the official view of the Society.

The speakers who were asked to open the debate were as follows:—

For the motion:—
Major R. H. Mayo.
Mr. Peter Masefield.
Mr. F. G. Miles.

Against the motion:—
Professor G. T. R. Hill.
Mr. A. Davenport.
Mr. L. A. Rumbold.

He would now call on Major Mayo to open the debate.

Major R. H. MAYO (Fellow): When one tries to compare the relative importance of two such features of transport as speed and comfort, one must first examine the questions whether and to what extent these features make conflicting demands on the designer or the operator. Both speed and comfort are essential for the success of air transport, and it is hoped they were not going to hear from speakers against the motion any accusation that they on this side fail to appreciate the importance of comfort. There is no suggestion that a single one of the essential requirements for comfort should be sacrificed in the interests of speed. In proposing this motion he not only admitted, but positively demanded, that every one of these essential requirements must be met.

For his own part, he had striven for a quarter of a century to achieve higher standards of comfort in air transport. He had been the bane of many designers by his insistent demands for greater comfort for both passengers and crew.

What he had sought to achieve was a standard of comfort properly related to the nature of the service—the length of stage, the number of stages per day, the number

of consecutive days required to reach the destination, and so on. He had travelled fairly far and wide by air, and had suffered acutely from the failure of some designers and some operators to meet the essential requirements for comfort. But he had never demanded a standard of comfort higher than was strictly necessary for the particular service concerned.

The essential requirements for comfort which must be met include: reasonable space per passenger (or member of crew), ventilation, heating and temperature control, lighting, the provision of food and drink as necessary, sound-proofing, lavatory accommodation, and, if the flight is to be made at high altitude, pressurising. He quite expected they would hear from certain authoritative speakers on the other side a plea for the provision of pressurising; if so, they will be wasting their words, because he was sure they all agreed that pressurising is an essential requirement which must be met for all high altitude services.

Only a few of these essential requirements have a primary effect on speed, but all have a secondary effect because they add weight, and this reacts on speed by demanding a larger aircraft for a given power plant.

Of all the essential requirements for comfort cubic space has the greatest primary effect on speed through its influence on hull size. Every soul on board, whether passenger or member of the crew, must be provided with reasonable leg room, elbow room and head room. He would leave it to later speakers to discuss what the word reasonable implied. For very short-haul services the standard of accommodation can obviously be reduced to a minimum. No one complains of the cramped seating of the motor-bus if his journey involves only a three-halfpenny stage. But the farther afield one is going and the longer one is going to remain on board, the better is the standard of accommodation required.

Where very long stages and more or less continuous flying over several days are involved, proper provision must be made for the service of meals, and a dining saloon may be an essential requirement for comfort.

Again, if flying is to be continuous throughout the day and night, proper sleeping accommodation may be an essential requirement. The point is that for every class of air service there is a certain minimum standard of comfort which must be provided, and the question of conflict with speed only begins to arise if and when that minimum standard of comfort is exceeded. He hoped the opposition would not object if from now onwards he referred to comfort in excess of this minimum standard as "luxury." This is, of course, purely a matter of convenience and is not a manœuvre intended to prejudice their case.

It seemed to him that if they were to solve the problem before them this evening, one or two of the many variables affecting the issue must be fixed. A reasonable comparison of two aircraft, one designed for speed and the other for luxury, cannot be made unless there are at least some features common to the two designs. He would assume that the two aircraft had the same power plant, and were designed to carry the same number of passengers and the same total pay-load by weight for the same range and the same stalling speed. These assumptions are in fact very generous to the opposition because where long range is concerned it may be impossible for the luxury plane to get the range owing to its low cruising speed. This will be particularly the case for a service such as London-New York direct, where the very strong headwinds involved accentuate the disadvantage of low speed. However, he was prepared to make this generous concession, and to assume that it is possible to design the luxury plane to meet both the range and pay-load conditions.

The luxury plane will, of course, be much larger than the high-speed plane, because it must carry all the weight increases involved, and the additional fuel necessitated by the lower speed. He would not set a numerical

value to the effect on speed, because he did not yet know how far the opposition were going to carry their demands for greater comfort. If they go the whole hog and ask for everything that the luxury passenger can desire, he suggested that the loss in cruising speed may well be of the order of 50 m.p.h. He would leave it to later speakers to give figures and would merely take a few examples to show how, in principle, speed is a better bargain than luxury from the passenger's point of view.

Starting with a very short-haul service on which the passenger requires to make only one stage, the saving in time with the high-speed aircraft will be only a matter of minutes, and this may be of little or no importance to the passenger. A difference of 50 m.p.h. in cruising speed will save only about ¼-hour on the London-Paris run, and in relation to overall time for the journey this may be unimportant. But on the other hand, if the passenger is only going to be on board for about an hour, luxury is also unimportant. Pre-war experience on the London-Paris route showed quite unmistakably that the passenger prefers to save that ¼-hour. The Handley Page 42 was a winner in its day because it offered a high standard of comfort and a cruising speed up to the standard of its time. But later on, when much faster aircraft came on the service, the traffic began to flow to them in spite of their lower standard of comfort.

But if the passenger has to travel over several stages, that ¼-hour per stage builds up into a substantial saving, and may make a great difference to the business traveller.

For medium stage services the effect of the higher speed will vary according to the nature of the service. He would take only one example—a very long-distance service, say, from England to Australia, with stages averaging about 1,000 miles. If the service runs through continuously by day and night, the additional 50 m.p.h. will result in a saving of about 12 hours or, say, a full working day. If, on the other hand, the service runs by day only and provides for night stops at selected stations, the higher speed will affect not so much overall time as the comfort of passengers. They will get approximately an additional two hours on the ground at each night stop, and, especially on the east-bound services (towards the sun), this will make all the difference between a good night's rest and the reverse. He thought there were few people who have had experience of this kind of journey who would not cheerfully forego luxury on board in order to gain that two hours on the ground at each night stop. Here, then, is a case where the real interests of comfort are served, not by additional luxury on board, but by higher speed.

He would take only one other example—the case of a direct service between London and New York, involving a stage of 3,450 miles, which is about the longest stage that is worth while in any part of the world. In this case the additional 50 m.p.h. may make a difference of five or six hours on the west-bound journey against the prevailing wind. At the higher speed an overnight service is possible; at the lower speed it is not.

Turning now to other aspects of this question, the provision of luxury on board involves this definite sacrifice of speed, but does not offer any compensating effect on the other features which go to build up success in air transport. He was thinking of such features as safety, reliability, regularity and economy, all of which are of vital importance to the ultimate success of air transport. So far from offering an improvement in any one of these features, additional comfort entails, through its adverse effect on speed, a definite sacrifice in all of them.

High cruising speed has a very definite and important effect on safety in operation. Assuming a common stalling speed for the speed and luxury planes, the former has the greater speed range, and this is an important factor making for safety in the event of partial failure of the power plant. Again, when unexpectedly strong headwinds are

encountered, the higher the cruising speed the less the effect on range and the greater the chance of reaching the destination with the margin of fuel provided. Captain Cripps, who is to speak later, would no doubt be able to amplify this argument from his own wide experience.

Reliability and regularity are features closely coupled with safety, and the advantage which the high-speed plane has in safety applies to these features also. Under adverse circumstances the pilot of the high-speed plane will have less need to open up his throttles, and less strain will be imposed on the engines. Not only will this enable the high-speed plane to get through to its destination with greater certainty, but in addition the operator will be justified in despatching the service with greater regularity in face of uncertain conditions.

It is proverbial that in all forms of transport high speed costs more, but that only applies where the high speed is achieved at a sacrifice of pay-load capacity, or by employing higher power. What they were concerned with was increased speed obtained by restricting comfort to the minimum standard necessary, and this represented a pure gain in economy. All the operating costs depending on flying time are directly reduced. These costs include fuel, oil, crew's pay, and maintenance and overhaul of aircraft, engines and all flying equipment, and they build up to more than half the total expenditure. The effect of a 50 m.p.h. increase in speed, obtained without sacrifice of pay-load capacity or increase in power output, is thus to reduce overall expenditure by more than 10 per cent. This is a reduction sufficient to determine whether a service can be run on a self-supporting basis or not. And apart from this, the small high-speed plane will be cheaper as to capital cost, standing charges, and maintenance and overhaul per hour, so that the overall reduction in expenditure will be far greater than the 10 per cent. due directly to the higher speed.

There are some who feel that these debates may be harmful to the Society because they are liable to lead to impassioned pleading rather than close reasoning. He had endeavoured to open up the debate on technical lines, and if he now ended by making an appeal for votes in favour of the motion, he hoped he would not be too severely criticised. He made this appeal solely on the merits of the case. He appealed particularly to the younger generation of designers, engineers and technicians to carry on the fight for speed, and to ward off the attacks of all comers. Do not concede too much to the demands for greater comfort; concede only what is essential for the service on which the aircraft will be employed. Go for high speed from the first and let the design shape itself round this fundamental. They should keep before them as a motto the words of the immortal and prophetic Milton: "And to thy speed add wings."

Professor G. T. R. HILL (Fellow): From the comfort of a Professorial Chair one may be allowed to go back over a period of 150 years, to the time when there was provided an example of very effective collaboration between Great Britain and the United States of America, in regard to the transport of black men from Africa to America, where they were employed as slaves. There was a shipping service across the Atlantic, presumably run for profit, without subsidy, and very intensive research was carried out as to exactly how many slaves could be stowed into a ship of a given size.

If the slaves were given comfort perhaps luxury, comparatively few could be accommodated on board, and that was not very profitable. On the other hand, if they were crowded so closely that many of them died *en route*, the shippers were not paid much at the end of the voyage because there were not many slaves left. As the result of research a balance was struck, and the figures showed that the greatest economy in slave transport was achieved when the

crowding conditions were such that about 20 per cent. of the slaves died on the voyage. It was most profitable to run the service on those lines.

He was not attempting to set up a target figure in respect of air transport! He merely put forward that illustration to indicate an approach or a kind of approach to the problem. They would picture the problem in regard to aircraft as one in which there is at one end of the scale all speed and no comfort, and at the other end of the scale all comfort and no speed. It is a fairly simple picture; they would have to decide upon an ideal combination of speed and comfort for any route or type of route.

The factors affecting comfort could be divided into the physical and mental factors. Major Mayo has mentioned the physical factors fairly clearly. There is the question of the cubic space required; and cubic space undoubtedly makes for comfort.

On the mental or psychological side, one of the things on which he thought they would all agree is that a sense of safety does contribute most materially to one's enjoyment of a trip. He had had the advantage of travelling by air during what might be called the new days, and he had been tremendously impressed by the fact that one can enjoy long trips by air without being "carbonised" or coming to any other harm. He supposed he had taken as long a trip by air as anyone will take, flying for five nights and two days at a speed which to-day may be regarded as being relatively slow; when air speeds are developed to "reasonable" figures, such a flight would carry anyone from this country to New Zealand.

He had had to undertake the journey not long after a very serious illness. He was the only passenger on the aeroplane, and arrived in New York as fresh as when he had left London a few days earlier. On these long trips there is available a lot of space and one is well looked after; people who take these trips need not look forward to arriving only half-conscious at their destinations.

With regard to this question of extra space and its cost in speed, consider travel by train. The first-class passenger does not expect to travel faster or to reach his destination before the third-class passengers, for more or less obvious reasons. But he does get more leg room.

He had made some sort of calculation as to the cost of extra comfort in terms of speed in air travel. It is very venturesome because he was sure the figures must be very variable; but his shot was that for a 10 per cent. addition of cubic space for passengers on a trans-Atlantic flight the cost in speed would be a reduction of about 1 per cent. That is a sort of target which he put up for attack.

Mr. P. MASEFIELD (Fellow): There are really two reasons why the motion is correct.

Speed is more important that comfort in air transport because:—

(i) it is more economic, and
(ii) it is more in demand.

This can be seen right through the history of air transport. It is a story of increasing speed and falling costs. Comfort has increased—though not steadily.

For instance, the old H.P. 42 was more comfortable in 1930 than the DC-4 is to-day—except that it took so long to get anywhere that other sorts of discomfort arose.

But the old H.P. 42—for all its built-in comfort—is dead; while the DC-4 is very much alive. Built-in headwinds are more potent in killing an aeroplane than is built-in comfort in prolonging its life. The reason why the DC-4 is alive and the H.P. 42 is dead is that the DC-4 is faster and so more useful.

The most comfortable form of air travel ever built was the rigid airship—at least, physically comfortable. But why is the super-comfortable airship dead? The answer is that it was too slow.

Looking back, all the emphasis has been on speed, not comfort.

He would like to make two points:—

(i) Speed is more worth while than comfort, and

(ii) Once a minimum standard of comfort is achieved, go for speed.

On the first point, suppose that they had a certain imaginary aeroplane fitted up to a certain standard of austere comfort. Now consider whether it is more worth while to take that typical aeroplane and sacrifice some of the pay-load to increase the *speed* or sacrifice some of the pay-load to increase the *comfort*.

In fact, what he was proposing, as an illustration, was this: Take the standard imaginary aeroplane with 5,000 lb. of pay-load for 500 miles at 200 m.p.h. Now sacrifice 1,000 lb. of pay-load, first to speed and then to comfort. What is the result? Which is the better?

Table I shows the basic assumptions —carrying passengers only on the "speed" and "comfort" versions.

(i) Taking the "speed version" first, and keeping the relative powers the same, obviously they had to put bigger engines in to achieve the same percentage of cruising power at a higher speed. The new engines

TABLE I. SPEED VERSUS COMFORT.

Transport Aeroplane "A" (Standard Version) 5,000 lb. of Payload for 500 miles at 200 m.p.h.

Transport Aeroplane "B" (Speed Version) 4,000 lb. of Payload for 500 miles at 215 m.p.h.

Transport Aeroplane "C" (Comfort Version) 4,000 lb. of Payload for 500 miles at 200 m.p.h.

OPERATING COMPARISON FOR 500 MILE STAGE.

	"A" Standard Version.	"B" Speed Version.	"C" Comfort Version.
Gross weight	30,000 lb.	30,000 lb.	30,000 lb.
Modifications	Standard	1,000 lb. payload sacrificed for increased speed (bigger engines and more fuel and oil)	1,000 lb. payload sacrificed for increased comfort (heavier accommodation and more equipment)
Take-off power	3,500 b.h.p.	3,900 b.h.p.	3,500 b.h.p.
METO power	3,000 b.h.p.	3,350 b.h.p.	3,000 b.h.p.
Cruising power at 10,000 ft.	1,500 b.h.p.	1,675 b.h.p.	1,500 b.h.p.
Percentage of METO power	50 per cent.	50 per cent.	50 per cent.
Fuel and oil consumption	700 lb./hr.	780 lb./hr.	700 lb./hr.
Specific combined consumption	0.465 lb/bhp/hr.	0.465 lb/bhp/hr.	0.465 lb/bhp/hr.
Cruising speed	200 m.p.h.	215 m.p.h.	200 m.p.h.
Block to block duration for 500 miles stage	3.0 hours	2.75 hours	3.0 hours
Block to block speed	167 m.p.h.	181 m.p.h.	167 m.p.h.
Required duration with reserves	5.75 hours	5.40 hours	5.75 hours
Still air range (no allowances)	1,150 miles	1,160 miles	1,150 miles
Weight of fuel and oil	4,000 lb.	4,200 lb.	4,000 lb.
Air-miles per imperial gallon	2.06 A.M.P.G.	1.99 A.M.P.G.	2.06 A.M.P.G.
Operating-miles per imperial gallon	1.72 O.M.P.G.	1.80 O.M.P.G.	1.72 O.M.P.G.

come out 800 lb. heavier and consume 200 lb. more fuel over the 500-mile stage, making up the 1,000 lb. sacrifice in pay-load in all and giving 125 m.p.h. extra speed.

(ii) The " comfort version " has the same engines as the "standard version." It results in 1,000 lb. higher weight of accommodation for the same number of passengers, say another 55 lb. weight of fittings per passenger. (Obviously, the way to do it is to pinch the space that would be used for freight and mails in the " standard version " and so make the passenger cabin bigger for the same number of passengers.).

Table II gives a comparison of weights and economic results. On the same cost-assumptions the passenger fare for the " speed version " works out seven per cent. less than that for the " comfort version "—obviously because in the " comfort version " they were adding weight for no return, whereas in the " speed version " they were adding weight and getting some extra speed in return for it.

In fact, a pound weight spent in gaining speed is more worth while than a pound weight spent in gaining comfort.

That leads to the second hard and fast point—all these things should be *hard* and *fast*. Once a certain minimum standard of comfort is achieved, go for speed.

(i) Because speed is less expensive for any given sacrifice in pay-load.
(ii) Because speed is more convenient.
(iii) Because speed makes possible greater regularity of service against head-winds.
(iv) Because speed increases safety.
(v) Because speed increases revenue-earning capacity.

The whole thing turns on the minimum acceptable standard of comfort. It is hard to define, but in Fig. 1 he had made a shot at it. He put these suggestions forward, not dogmatically or as fixed limits, but merely as points round which to debate.

Obviously the standard of comfort required must depend on the duration. Perhaps the

TABLE II. OPERATING COMPARISON FOR 500 MILE STAGE.

	"A" Standard Version.	"B" Speed Version.	"C" Comfort Version.
Weights:—Power plant ..	7,000 lb.	7,800 lb.	7,000 lb.
Tare weight	20,000 lb.	20,800 lb.	21,000 lb.
Crew (4)	800 lb.	800 lb.	800 lb.
Stores	200 lb.	200 lb.	200 lb.
Fuel and oil	4,000 lb.	4,200 lb.	4,000 lb.
Payload	5,000 lb.	4,000 lb.	4,000 lb.
Disposable load	10,000 lb.	9,200 lb.	9,000 lb.
Gross weight	30,000 lb.	30,000 lb.	30,000 lb.
Passengers carried	18	18	18
Weight of passengers baggage	4,000 lb.	4,000 lb.	4,000 lb.
Freight and mail	1,000 lb.	Nil	Nil
Overall operating cost per hour	£35	£36	£35
Operating cost for 500 mile stage	£105	£99	£105
Cost per capacity ton mile ..	20.0 pence	23.7 pence	25.0 pence
Break-even passenger fare (62½ per cent. load factor)	£7 10s. 0d.	£8 16s. 0d.	£9 7s. 6d.
Cost increase	—	18 per cent.	25 per cent.
Ton operating-miles per imperial gallon	4.3 T.M.P.G.	3.6 T.M.P.G.	3.44 T.M.P.G.
Ton operating miles per hour	417 T.M.P.H.	362 T.M.P.H.	334 T.M.P.H.

lack of vibration in jet-propelled aeroplanes may reduce the built-in weight of comfort necessary. Anyway, here is a shot at some very approximate standards.

Thus, at 150 m.p.h. block to block, for a range of 3,000 miles they needed the large amount of built-in comfort appropriate to twenty hours in the air. But at 500 m.p.h.

SUGGESTED MINIMUM STANDARDS OF COMFORT
TRANSPORT AIRCRAFT

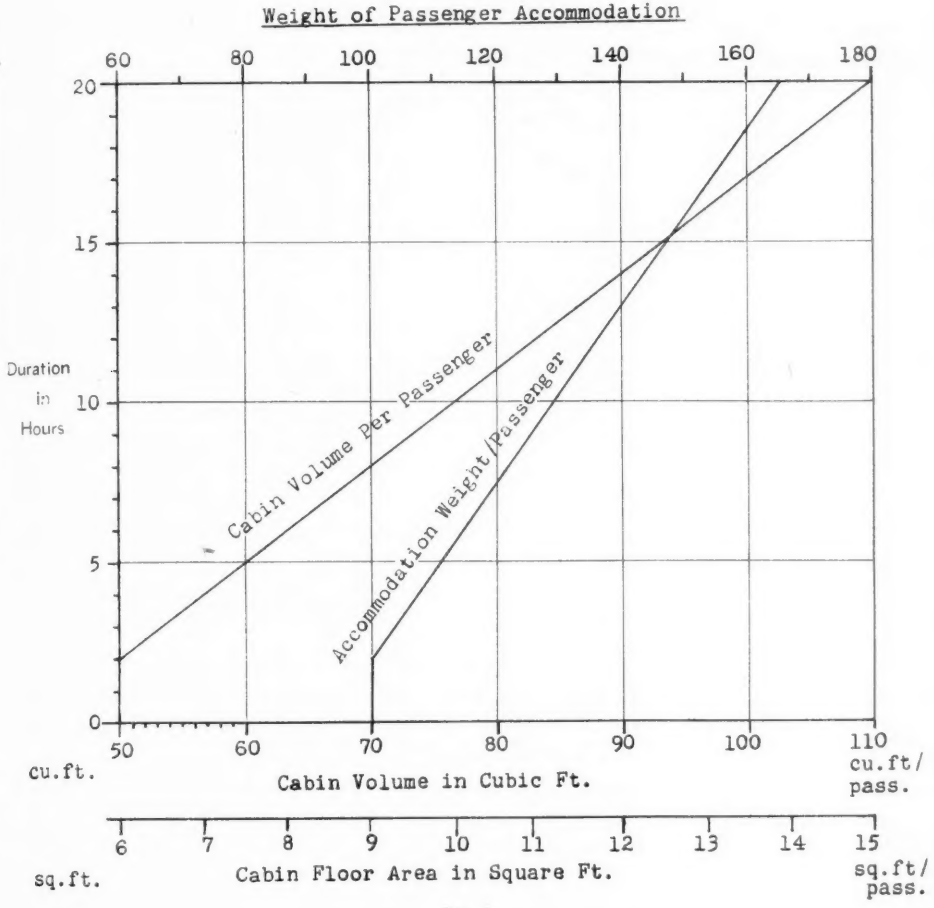


Fig. 1

But, taking them as a basis, one can illustrate the fundamental. It is this; and it is shown in Fig. 2:—

For any duration—and hence for any minimum standard of comfort—the faster one flew, the longer range could be achieved for a lighter weight.

they needed only such comfort as is appropriate to six hours in the air—twelve hours' shorter time.

How that amount varies, on the basic assumptions, is shown in Fig. 3. For an operating stage of 2,000 miles at 200 m.p.h., which is ten hours' duration, they

DURATION AND OPERATING RANGE AT VARYING BLOCK TO BLOCK SPEEDS

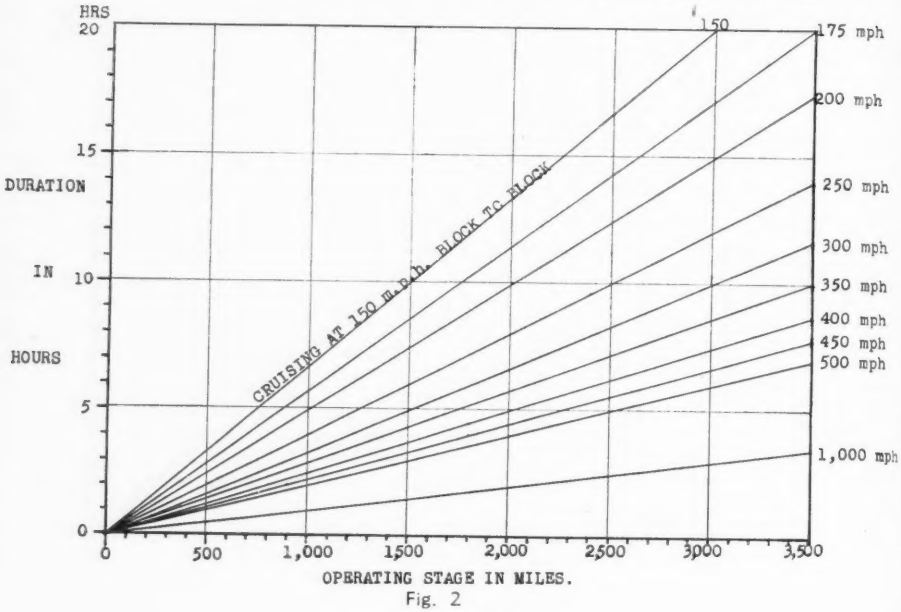


Fig. 2

THE ADVANTAGE OF SPEED

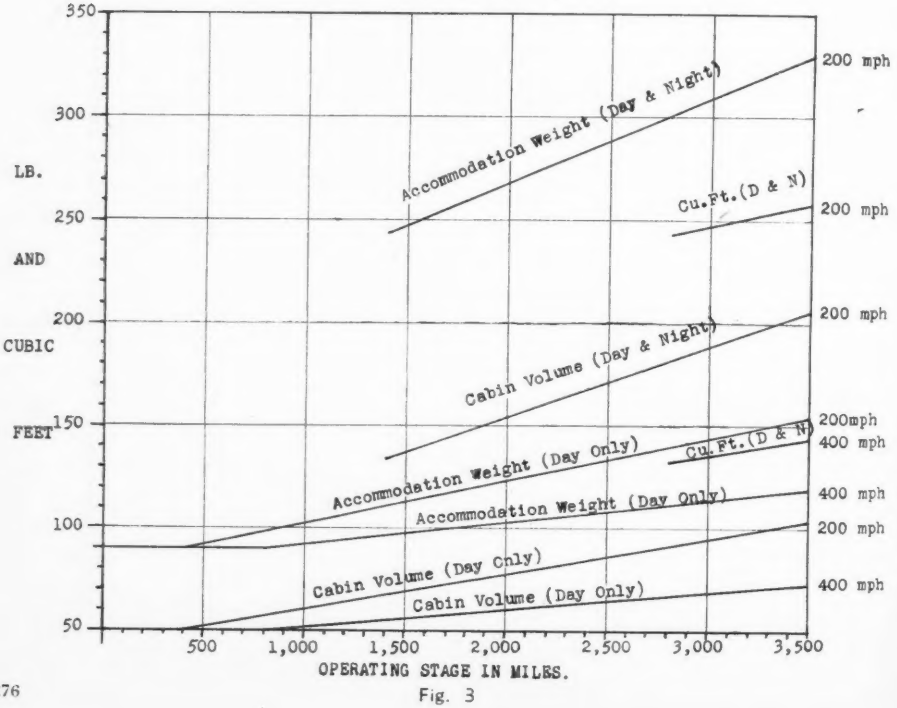


Fig. 3

may need 77 cubic feet of cabin volume per passenger and 130 lb. of accommodation weight. But for the same range at 400 m.p.h., which is five hours' duration, they would need only 60 cubic feet of cabin volume per passenger and 103 lb. of accommodation weight. And on a big aeroplane with many passengers, that is a big difference. For a high-speed jet-propelled aeroplane they could afford to have a smaller diameter fuselage and pack people in more tightly if they were going to get there quickly.

There is another point. Day and night travel. All the figures so far have been for day seating only. If they were going to put in bunks it would cost them at least 20 lb. per bunk with bedding and blankets. But, much more serious than that, one can only "sleep" about half the people one can "seat." A bunk takes up the space of two seats. So in a convertible day and night aeroplane they would have to sling out half the capacity-load of passengers at night and so double the cabin volume per night passenger, and double the accommodation weight per night passenger, *plus* 20 lb. per passenger for his bunk and bedding.

So a good deal of pay-load has to be sacrificed to provide the comfort of bunks. At 200 m.p.h. for 2,000 miles—the ten-hour duration—the cubic space per passenger goes up (on the assumptions) from 77 cubic feet to 154 cubic feet, and the weight from 130 lb. per passenger to 280 lb. per passenger seat—that is, two seats making one bunk per passenger. He thought it could be done for less, but it shows the trend. At any rate, at 400 m.p.h. it is much less.

He submitted that it was never worth while putting in bunks for durations of less than seven hours. So, apart from very long through-flights, where day and night flying may be required, if flights can be cut down to seven hours or less, bunks will not be needed. Another argument for speed.

A stage length of 3,500 operating miles is about the longest they need bargain for. That means that a block-to-block speed of 500 m.p.h. will be required to cover this distance—3,500 miles—in seven hours. That is not impossible by any means. Then, even on the England-Australia route, halfway round the world, it should be possible to cover 7,000 miles in the 24 hours *and* for the passenger to have seven hours in bed in an airport hotel at night—only one night on the way. And that is much more

TABLE III. CABIN VOLUMES AND ACCOMMODATION WEIGHTS.

Duration.	Range. Operating Stage.		DAY ONLY. Per day passenger seat.			DAY AND NIGHT. Per night passenger seat.		
	At 200 m.p.h. block to block.	At 400 m.p.h. block to block.	Cabin Volume. cu. ft.	Floor Area. sq. ft.	Accommodation Wt. lbs.	Cabin Volume. cu. ft.	Floor Area. sq. ft.	Accommodation Wt. lb.
Hours.	Miles.	Miles.						
0	0	0	50	6.0	90	—	—	—
1	200	400	50	6.0	90	—	—	—
2	400	800	50	6.0	90	—	—	—
3	600	1200	53	6.6	95	—	—	—
5	1000	2000	60	7.5	103	—	—	—
7	1400	2800	67	8.5	112	134	17	244
8.75	1750	3500	72.5	9.4	124	145	18.8	268
10	2000	4000	77	10	130	154	20	280
12	2400	4800	84	11.2	136	168	22.4	292
15	3000	6000	94	12.7	148	188	25.4	316
17.5	3500	7000	101.5	13.8	156	203	27.6	322
18	3600	7200	104	14	158	208	28	336
20	4000	8000	110	15	165	220	30	340

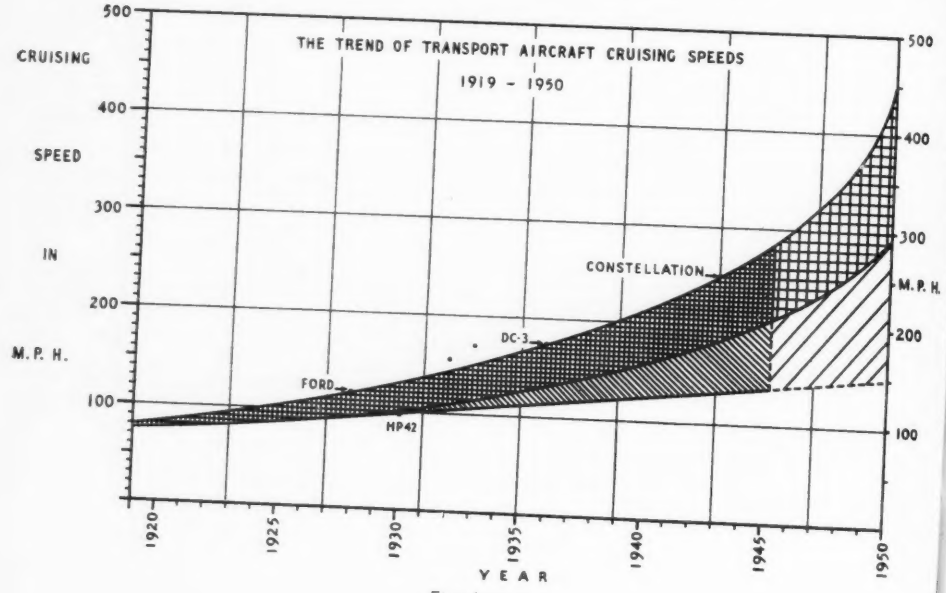

THE TREND OF TRANSPORT AIRCRAFT CRUISING SPEEDS
1919 - 1950
CRUISING SPEED IN M.P.H.
500
400
300
200
100
CONSTELLATION
DC-3
FORD
MP42
1920
1925
1930
1935
1940
1945
1950
YEAR

Fig. 4

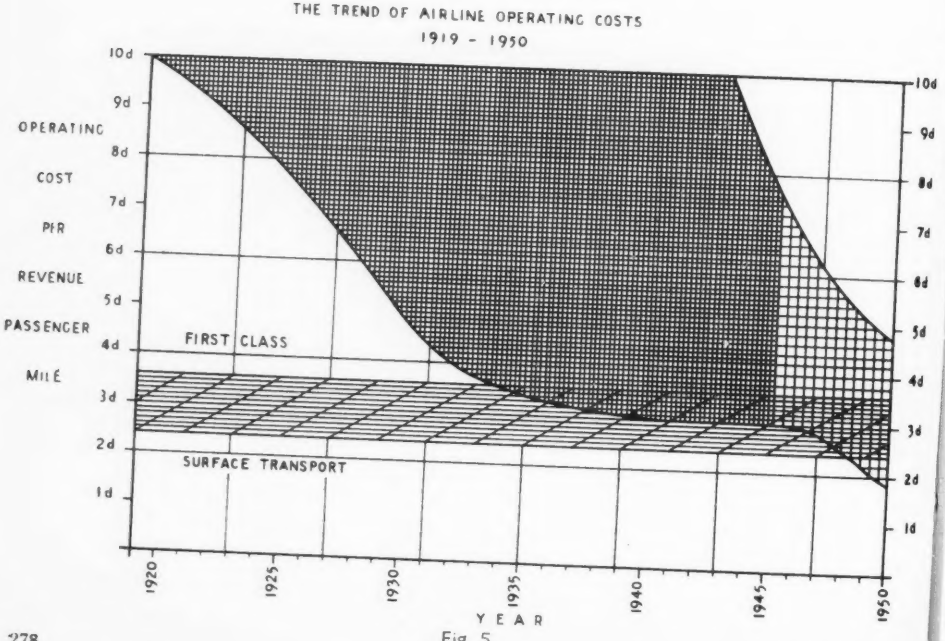

THE TREND OF AIRLINE OPERATING COSTS
1919 - 1950
OPERATING COST PER REVENUE PASSENGER MILE
10d
9d
8d
7d
6d
5d
4d
3d
2d
1d
FIRST CLASS
SURFACE TRANSPORT
1920
1925
1930
1935
1940
1945
1950
YEAR

Fig. 5

economic than day and night provision. If they want to get there really fast, they can sit up for one night and do the whole journey in about 24 hours.

Table III shows comparisons of cabin volume and weights at 200 m.p.h. and 400 m.p.h. For a range of 3,500 miles at 400 m.p.h. they saved 32 pounds per passenger compared with 200 m.p.h., and, even more important from a drag point of view, they saved nearly 30 cubic feet per passenger by putting up the speed.

But whatever one thought of exact figures, which are not exact at all, Fig. 4 shows how inescapable is the march of science.

Man's taste in comfort is static—or more or less static. But man's taste in speed is dynamic.

The curve of trends of cruising speed is going up. They were going to see a swifter advance than ever before, now. After all, Whittle first thought of his gas turbine in terms of civil aircraft. At the same time as speed has gone up, safety has increased.

The whole trend is for the speed to go up and for the comfort to remain fixed. So speed *is* more important than comfort.

This speed has been going up while the cost has been coming down, as Fig. 5.

So, set comfort, increase speed and reduce costs.

What is wanted for air transport is flying services for the masses. To get that, they must have speed, safety, frequency of service and low cost. Comfort can reduce all these.

Reference has been made by Professor Hill to the transport of slaves from Africa to America. He suggested that if he had transported his slaves across the Atlantic faster than they were in fact transported, none of them would have died, or at least, not so many would have died. Again, if one does not like air travel, then with greater speed one will have less time in which to feel unsafe.

Mr. A. DAVENPORT (Fellow): Having travelled in aircraft and suffered from cold, and so on, he was in favour of comfort so far as civil aircraft are concerned. If he were dealing with military aircraft he would be in favour of speed. He emphasised that it is in regard to civil passenger air liners, *as distinct from military and mail-carrying aircraft,* that comfort is the more important consideration.

"Comfort" has been defined as "to relieve from pain or distress," or "feeling a state of well-being." He was assuming, as terms of reference, that the comfort they were talking about that evening was intended to go much further than the former definition.

As to an exact definition of speed, it is assumed that it is intended to be very high as compared with other methods of transport or even with present speeds of air travel.

They had heard from Mr. Peter Masefield that increased speed reduces costs. He could not agree. If a curve is drawn it will be found that the cost goes up out of all proportion to the increase of speed.

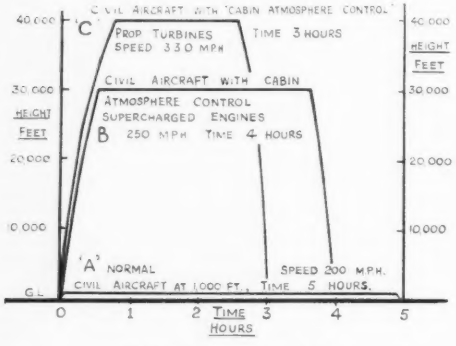
In most forms of transport other than aircraft it is possible to obtain speed without comfort, as, for example, in the case of the motor cycle or the speedboat. But for long-distance or business appointments the motor car, or even the "Queen Mary," giving comfort as well as speed, are used if possible This comfort has been proved to be a most essential requirement, and it will be proved necessary also for aircraft.

All the arguments used by Mr. Masefield ignored the problem of height. The first cost of aircraft provided with comforts such as will be described will be greater than that of aircraft not so provided; but the extra cost will be fully repaid by the greater proportion of passengers who will travel in the more comfortable type of aircraft.

By providing complete cabin atmosphere control—he thought that expression was better than "pressurisation" because ordinary men and women do not like to feel that they are to be "pressurised"—the passengers will be able to travel at high altitudes,

where the aircraft will be clear of icing conditions and will be able to take advantage of favourable weather and winds. With either supercharged piston type engines or pure jet or propeller turbine units the aircraft will be able to attain a high and economical cruising speed without any appreciable loss of pay-load. Another important technical point is that the fuel consumption of the piston engine will be substantially the same at height as at ground level, and much less in the case of the propeller turbine. Therefore the fuel capacity is unchanged for a given range. He was thinking of an air liner carrying fifteen or more people.

Fig. 6 shows in graphical form the various conditions of three types of aircraft. It



RANGE 1,000 MILES

Fig. 6

indicates that over a range of 1,000 miles an aircraft with cabin atmosphere control is able to fly at 30,000 ft. and to complete the journey in comfort in one hour less than the aircraft of normal type flying near the ground, and assumed to be powered by the piston type engine; the most economical cruising speed of the normal type aircraft is assumed to be 200 m.p.h. Further, if the aircraft with cabin atmosphere control is fitted with propeller turbines and flies at 40,000 ft., the time occupied in the flight of 1,000 miles is only three hours, or a saving of two hours as compared with the normal aircraft flying low. Thus the ability to fly high not only saves time, but provides comfort as well.

There is possibly a misconception as to the extra weight entailed by the fitting of pressurising equipment.

Table IV shows that the blowers, control, discharge and safety valves, mountings, ducting and main structure and cabin weight increase will not exceed 3.5 per cent., and may not exceed 3 per cent. of the total

TABLE IV.

ADDITIONAL OVER BARE NECESSITIES FOR PURE HIGH SPEED AIRCRAFT (OXYGEN 1000 LBS.).

WEIGHT OF PASSENGER COMFORT AND EQUIPMENT FOR AN 18-20 SEATER AIRCRAFT.

1. *Heating and Ventilating.*	
Heater and controls for heater (Janetol type)	40 lb.
Petrol for 10 hours	56 lb.
Humidity equipment + water (compressor type, etc.) ..	120 lb.
Fan and wiring for motor (circulation in cabin duct and through heater)	35 lb.
Air ducting (22 S.W.G. alum) ..	44 lb.
Instruments, etc.	15 lb.
Total heating and ventilating ..	325 lb.
2. *Lagging for Heat and Sound Proofing.*	
Lagging 2 × ¾in. layers of 'Kapok'	330 lb.
Facing and trimming material ..	105 lb.
Floor covering	65 lb.
Total surface covering	500 lb.
3. *Seats, etc.*	
Extra weight of upholstered and adjustable seats (25 lb. ea.) ..	500 lb.
Curtains, folding tables, etc. ..	100 lb.
Total seats, etc.	600 lb.
4. *Toilet Provision.*	
Total increased toilet provision ..	60 lb.
5. *Galley.*	
Cooking equipment and fuel ..	100 lb.
Cutlery and crockery	40 lb.
Food and drink (if obtainable) ..	75 lb.
Total provisioning	215 lb.
Total passenger comfort weight allowance (non-pressurised) 3.4 per cent. of 50,000 lb.	1700 lb.

weight of the aircraft. In the latter case it would be 1,500 lbs. on an aircraft having a total weight of 50,000 lbs. He contended that this is a very small increase of weight for the benefits obtained.

Table V indicates the weight increase for equipment above the bare necessities, by which he meant equipment for heating and ventilating, lagging for heat and sound-proofing, extra comfortable seats, toilet provision and equipment for the cooking galley, is 1,700 lbs., representing 3.4 per cent. of the total weight of the aircraft. This extra weight includes provision for super or luxury comfort. But it also includes provision for heating and ventilating, which is necessary in any aircraft if it is to carry passengers at all. So that most of the equipment will be included in any case. It is difficult to see how much of the weight which gives luxury comfort can be left out.

To summarise:—

(1) Taking advantage of flying at altitude in complete comfort is admitted to increase the weight of the aircraft.

(2) In spite of this increase in weight, engine characteristics and supercharging can be so arranged that, instead of reducing speed at height, some increase is obtained as compared with aircraft flying near the ground.

(3) The ability to fly high ensures greater safety by avoiding icing and other adverse weather and wind conditions.

(4) Running cost per ton-mile will not be increased by flying at greater height and with the provision of comfort.

(5) The pay-load is not appreciably reduced by flying high.

(6) The business or professional passenger requires, and will insist upon, comfort so that he will arrive at his destination ready for his conference or work, not cramped, frozen or fatigued.

(7) Oxygen apparatus for passengers and crew is not a solution; passengers will not be persuaded to use oxygen masks. Further, their weight is by no means negligible, being approximately 1,000 lbs. in a 50,000 lbs. aircraft.

TABLE V.

WEIGHT OF PRESSURISING EQUIPMENT SUITABLE FOR AN 18-20 SEATER AIRCRAFT.

1. *Equipment.*	
Blowers—2-15 lb./min. size ..	64 lb.
Air cleaner	12 lb.
Silencers	40 lb.
Coolers	24 lb.
Non-return and spill valve ..	13 lb.
Safety valves (two for safety) ..	7 lb.
Master control unit and panel (brasses)	15 lb.
Discharge valve	10 lb.
Inwards relief valve (for rapid descents)	5 lb.
Remote controls	30 lb.
Total equipment items	220 lb.

(*Note.*—These weights are either actual or close estimates.)

2. *Incidental Items.*	
Mountings for above items and ducts	80 lb.
Duct and regulating flap for cooler	10 lb.
Electric wiring for remote controls	15 lb.
Extra weight of cabin and cockpit windows	150 lb.
Extra weight of entrance doors*	100 lb.
Control rod wiring and piping gaskets	100 lb.
Total incidental items	445 lb.

(*Note.*—These weights are general estimates subject to wider tolerances than those above.)

Total pressurising equipment installed, say 1.5 per cent. of all-up weight of 50,000 lb., 1.35 per cent. (total of above)	675 lb.

The increase of *main structure weight* will occur mainly: (i) In provision of a bulkhead at the rear of the fuselage (preferably hemispherical or conical in shape), and (ii) around the wing fuselage attachments, and in all may be from 1-2 per cent. of the all-up weight 500-1000 lb. 1250 lb. 1750 lb.

Then total weight due to pressurising of *all-up weight* 2.5 to 3.5 per cent.

* Provides for outward opening baggage compartment door.

(8) The majority of those who travel by air will be middle-aged people who have the money to pay for it and will expect comfort from the airlines.

Mr. F. G. MILES (Fellow): What is the proper function of a transport aeroplane? What is the quality which the Greeks called "arete"—denoting perfection in function? In a knife, for instance, they demanded that it shall cut straight, clean and true—but first of all that it shall *cut*. Sharpness is therefore the important part of the excellence of a knife and, without sharpness, the most beautiful haft, the most slender blade, the most jewelled scabbard, are only vanities.

He was going to argue that, likewise, the proper excellence of a passenger aeroplane lies in the *swift* transport of people from place to place. He was not compelled by the terms of this debate to discuss the relative merits of other values than speed and comfort, but he believed many would agree that the principal five parameters are (1) safety; (2) regularity; (3) speed; (4) cost; (5) comfort, in that order.

Of course, in special cases some of these values may change importance. For instance, a rich man might value comfort over cost, whereas a poor man would most certainly value cost more than comfort. And, taken by and large, it is obvious that certain others are *not* reasonably interchangeable. Regularity should not be exchanged for either speed or comfort.

All these terms are relative. They could not exchange the speed of light for discomfort of the rack without making the debate absurd. At some point lack of comfort degenerates into pain and speed approaches impossibility. Therefore, he assumed a minimum standard of comfort for a passenger aeroplane in terms of something they knew. Let them take the ordinary third-class railway carriage as the immediate minimum. And let them take speeds between 87 and 450 m.p.h. The former is that of Imperial Airways before the war on its large and comfortable biplanes, the latter is to-day a possible speed.

Now any question must take the form "Do you prefer to fly a distance of, say, 300 miles in the sybaritic luxury of a first-class ocean liner at 87 m.p.h., taking 3½ hours, or will you bear with the lesser comfort for only forty minutes?" He thought they would probably compromise and plump for first-class railway carriage comfort at 300 m.p.h.

There are more important cases. Speed and comfort are relative terms, and most people would find it much more comfortable to sit on a hard chair in a noisy aeroplane for half an hour, than in the most luxurious armchair in a beautifully silenced and roomy cabin for two hours on a bumpy day, and there are cases where provision of too much comfort may be dangerous if it involves sacrificing speed. On the Atlantic crossing, for instance, he contended that a maximum cruising speed of much less than 300 to 350 m.p.h. is actually dangerous unless the weather service can forecast, accurately, strong headwinds. Even if the weather service is perfect, the slow aeroplane achieves safety at the cost of regularity.

Speed is safety, and safety is comfort of mind over even shorter routes.

There is a point, a little away from the subject, that occurred to him forcibly in thinking about this debate, and that is the price of comfort can be high in cost rather than speed. Take a 20-passenger aeroplane on which the weights allow them to provide a minimum standard of comfort at 20 lbs. per passenger. If they give real luxury at 100 lbs. per passenger they have a difference of 1,600 lbs. between the two standards—roughly equivalent to ten passengers—therefore the "austerity" version could be operated at less than two-thirds the fare! There is sometimes more comfort of mind in paying a fare they could afford at the expense of a slightly harder seat.

Comfort is comfort of mind plus comfort of body. There is more comfort of mind

ge.ting to one's destination quickly than in delaying in circumstances that may be dangerous. But, mainly, most serious travellers want to get to their destinations quickly. To do so means comfort of mind.

He submitted that almost the sole justification of air transport is its superior speed. The very nature of the aeroplane—its comparatively cramped accommodation and the special need for eliminating unnecessary weight, means that potentially it is likely to be much less comfortable than a train or a ship. Nevertheless, judged on a journey basis of time rather than miles, it is already far more comfortable than any surface transport.

He need hardly add that they should try to improve the standard of comfort as well as of every other aspect of aeroplanes. He would, in designing an aeroplane, think long and hard before he gave up trying to give more comfort than rival aeroplanes, but he did suggest that, within reasonable limits, where there is a decision to make between comfort and speed (safety not being affected) they should plump for performance.

This country has a frightening task ahead of it if it believed that it must not accept a minor place in the air future of the world. They had missed the importance of speed until now, and no excuse for slowness and inefficiency of operation can be given on the grounds that the armchairs are comfortable.

There will apparently be no competition in the home air to give the passenger a chance to show by his preference whether he likes speed or comfort or cheapness best. Therefore they might go catastrophically wrong.

Some time ago he was called to America on urgent business and arranged to fly from Ireland in a Boeing Clipper. That is a very comfortable machine. But after they had been flying for a few hours the pilot had no alternative but to return to Ireland because there was a 90-knot headwind and the petrol on board would not enable them to reach America. They had to wait in Ireland for the wind to drop to 30 or 40 knots. At that stage the average speed from the London office to Ireland was $1\frac{3}{4}$ miles per hour, and was beginning to fall further towards zero!

Too much comfort may be dangerous if speed is sacrificed. They must assume that it reduces speed. A cruising speed below 300 to 350 m.p.h. is actually dangerous unless weather reports show that the weather is good.

Mr. L. A. RUMBOLD: The subject of the debate is whether speed is more important. Modern aircraft travel at high speeds, speeds far above those of other means of transport; but they do not provide the very best in the way of comfort. He did think that, with the co-operation of the operators, the public and the designers, they should attain a very fine level of comfort. The operators depend on the public to use their aircraft services, and the best way in which to increase the use of aircraft by the public is to give them relaxation and contentment when travelling.

During the last twenty years he had been attempting to provide good interiors for aircraft. He had flown in practically all types of aircraft, except the single-seater machines, before and after furnishing; that experience gave one quite a good idea of what it is like to travel in an aircraft without comfort. He flew often in empty fuselages, to take readings of frequency of vibration, noise, to search for draughts, and all kinds of things, and some of the machines in which he had flown have been really painful. One could not speak to another person inside the aircraft, owing to the noise; and when one had landed, after a flight of only twenty or thirty minutes, one was quite deaf for a time. But after giving the aircraft a little attention in order to provide a little comfort, they could fly without being frozen and they could talk in comparative comfort.

Speakers had told them to-night that speed is cheap. From what he knew of speed, however, it is very costly, and ultra stream-

lining means reducing space available in the machine and reducing pay-load.

On the other hand, if reasonable comfort is provided in civil aircraft, satisfied customers will result.

With regard to the weight of comfort equipment, if there is proper co-operation with the design staffs in designing interiors, they could get down to a very low weight. The design of the interior must be incorporated in the design of the machine as a whole, and during the building of the machine the necessary ducts, inspection places, and so on, must be provided. A great deal of research is being conducted into the use of elektron and of certain types of plastics so that the weight will not be considerable.

At the moment he had three designs of interiors for three designs of machines. One is termed, he thought, the " Flying Char-a-banc," another is a European general service machine, and the third is an ultra luxury aeroplane. These different types must be treated in different ways; so long as each type is treated reasonably and sensibly, having regard to the duty it is to perform, there is no reason why the provision of reasonable comfort for aircraft passengers should entail considerable increase of cost or of weight.

DISCUSSION

Captain CRIPPS: From the point of view of a pilot, he was very interested in speed, for it seemed to him that it was one of the greatest safety factors on a route such as that across the Atlantic. It seemed that the success of the " Liberators " on that route was due entirely to the high performance of those machines. The eastbound crossing was easier than the westbound because a machine travelling west across the Atlantic had to face extremely high headwinds, and one could not possibly cope with the route except in an aeroplane of very high performance. It was exceedingly fortunate for those who were flying that route that the machines had a very high performance.

To give some idea of the performance necessary in a trans-Atlantic aeroplane, Captain Cripps gave some data with regard to winds during the winter of 1942-43. On the eastbound crossings there were three very high winds, one of 93 knots, one of 87 knots and one of 65 knots, those figures representing the average throughout the whole of each flight. On some west-bound flights there were winds of 70, 63 and 58 knots respectively. The amounts of petrol left in the tanks at the conclusion of the flights were very small, and it would seem that those conditions were really beyond the capabilities of an aeroplane which had to be flown commercially. It would be quite impossible to use a luxury Super 42 for flying the Atlantic, in view of the conditions that were likely to arise; at any rate, it seemed ludicrous to anyone who had had much experience of the route.

Another very important matter to be considered in relation to such a route, apart from the fact that the aeroplane must fly very fast, was that it might at any time have to cut out one engine; so that it must be able to carry enough fuel to enable it to reach its destination on three engines against high winds. That matter must be looked into very seriously; it might not be regarded very seriously at the moment, but it must be after the war. It would be necessary to provide a very much greater fuel reserve than many people at the moment imagined would be required.

Mr. W. E. PETTER (Fellow): None of the speakers who had supported speed, and least of all Major Mayo, had suggested that comfort should be thrown overboard; it was only when they had arrived at the stage of really luxurious aircraft that the speed merchants had made a case.

It seemed that it was necessary to decide what was comfort. The minimum standard of comfort would cost very little in speed.

There must be control of temperature at between 65° and 70°F., coupled with adequate ventilation; the noise level must be below 70 decibels; there must be no fumes, or at least, if there were fumes, the passengers could not stand them for more than about an hour, which meant that for long journeys they must fly in pressurised cabins at high altitude; seating comfort must be at least as good as that of a good motor car; there must be provision for feeding the passengers at intervals of four hours; and the passengers simply must not be kept waiting about on aerodromes. Punctuality was a very important factor in respect of comfort.

The weight cost of providing comfort to that minimum standard would not be more than 80 lbs. or thereabouts per passenger, so far as the actual equipment was concerned; so that on a 20-seater aircraft the weight of the comfort equipment would be about 1,600 lbs. In addition there was the extra weight of the structure to enable it to carry the chairs, heaters, and so on, which would amount to 1,300 or 1,400 lbs. So that the total extra weight would be about 3,000 lbs. That would reduce speed by not more than 10 m.p.h., say, from 250 to 240 m.p.h.

That provision did not represent luxury, but was the minimum essential for air travel. He urged that the meeting, when voting, should remember that they were discussing comfort and not luxury.

Air Vice-Marshal D. C. T. BENNETT (Fellow): He felt very strongly in favour of speed. The air transport business was not to be run as an amusement, but for the benefit of human beings; it was for them that the air transport operators must cater if British air transport were to survive.

Recalling some of his experiences on the air routes of the world, he said that without a shadow of doubt Imperial Airways had provided the best comfort in the world for aircraft passengers. Their machines had plodded along, however, at rather slow speeds; and fortunately, there were other airlines equally slow. He could remember disgruntled passengers lolling in their comfortable seats, thoroughly irritable and in every way unpleasant amongst themselves and with everybody with whom they came into contact, including the most charming passenger staff the world had ever known. On one occasion a comfortable old man, looking through the window of the aircraft, had noticed to his amazement that that Imperial Airways machine was actually overtaking a Littorio aircraft; and immediately the whole of the passengers had become delighted, satisfied customers, just because the machine in which they were travelling was faster than another. Human nature could not resist the lure of speed.

Imperial Airways had provided very great comfort in the machines on its eastern routes; but often the passengers made very rude comments because the K.L.M. machines travelled a little faster. The fact that the British machines were a little slower than the K.L.M. had given rise to the most tremendous ill-feeling he had ever seen on the part of people of the British Empire.

It was true that those examples were from the past; but human nature had not changed in that respect. It was of no use merely comparing the speed of aircraft with that of other forms of transport and saying that aircraft was sufficiently fast to meet all the customers' needs. The contrast in the future would not be as between aircraft and other forms of transport, but between aircraft and aircraft. Those who were conducting civil aviation would have to travel really fast; already we in the British Empire had the aircraft, and we must take full advantage of it.

Group-Captain B. E. BECKER (Associate): It must be admitted, perhaps with some regret, that time was becoming an ever more important factor in their lives; it followed, therefore, that they must avoid waste of time. But it was very easy to accept the idea

that in order to save time they must necessarily increase speed. He submitted that speed was not the only factor contributing to the saving of time or the avoidance of loss of time, and that by paying attention to comfort they might save time.

He urged that discomfort produced physical fatigue and mental fatigue; and the medical profession would agree that some time was needed to overcome the effect of both those forms of fatigue. He recalled an experience of Mr. Rumbold, who, after flying in a very fast machine, had had to be lifted out of it and laid on the ground for twenty minutes in order to recover his equanimity. What was the advantage of gaining a certain amount of time by speedy transit if they were to waste time subsequently lying prostrate, recovering from the rigours of the journey? They must provide such a degree of comfort, even at the expense of speed, as would ensure that passengers arrived at their destinations in a fit state mentally and physically to undertake the duties for which they had travelled or to enjoy the pleasures which they hoped to find at their destinations.

Group-Captain G. W. WILLIAMSON (Fellow): Summing up in favour of the motion, he said the most comfortable aeroplane could never be made any more speedy; but the fastest could at any time be made comfortable enough for Royalty.

The general public would most certainly continue to travel to Scotland by the fastest train, or to Paris by the fastest aeroplane.

It was not as though the standard of comfort need reach a level beyond that suited to the length of the journey. When rations ceased to be exiguous, some of them would be better padded and might be said, in the words of Emerson, to " carry our comfort about with us." Comfort proportionate to the length of the journey meant that speed was in itself a form of comfort; and those who voted for speed would undoubtedly vote also for a standard of comfort on long journeys which could not be achieved by the more cushioning of seats or beds.

It had been maintained that comfort was a form of safety, and that the slower the aeroplane the more comfortable it must necessarily be. That was an obvious fallacy, and pilots or engineers, passengers and operators, had unfortunately learned by bitter experience that the whole world preferred the fast aeroplane to the comfortable one.

In the Oxford Dictionary he had found the quotation " Speed is safety . . ."; but it went on to state ". . . when skating over thin ice." However, he stressed that in aircraft operation speed was safety, especially for the pilot. The pilot was made as comfortable as possible; the one other thing they could do to make him even more comfortable, and safer, was to give him more speed. A journey of four hours rather than six hours meant two hours less nervous tension for the pilot; two hours less in which something might go wrong; 50 per cent. more time in which the aircraft could be thoroughly serviced on arrival; more speed with which to fight headwinds or circumvent a change in the weather. Not even pressure cabins and air-conditioned accommodation would draw passengers to aircraft which required six hours for a four hours' journey.

Dr. Warner, in his address last year, had discussed the matter from the passenger angle. He had said that if it were necessary to pay extra for speed, approximately equal numbers of passengers would pay 60/- for a two-hour trip as compared with those willing to pay only 40/- for a three-hour trip.

Only that day the *Daily Telegraph* had published a paragraph on air travel in comfort; it had stated that 66 per cent. of the passengers had wanted more speed.

Illuminated panels showing the progress of the flight of an aeroplane, and a news tape service, were among the things which the " comfort crowd " would thrust upon us.

One of the disadvantages of the slow and comfortable aircraft was the possibility of a drift away from aviation to surface transport. Recalling the service to Berlin before the war, he said that even those who were concerned with aircraft had chosen to travel at 9 o'clock at night from Liverpool Street (London) instead of getting up at some ungodly hour next morning to arrive at Croydon by 8 o'clock. In either case one reached Berlin in time for tea. Similarly, the journey from London to Liverpool could be made by train only forty minutes longer than by air, door to door. One of the lessons to be learned was that, not only must aircraft be faster, but there must be more rapid means of getting passengers from terminal airports to their destinations.

Addressing the Manchester Association of Engineers last year, Sir Frederick Handley-Page had said:—

> "Whilst the 'Hannibal' introduced a new standard of comfort in air travel, with its saloon and kitchen accommodation for forty passengers, the general demand of other European airlines was for the smaller and faster aircraft which for the same capital outlay could provide a more frequent and quicker service, and were less subject to variation in time schedules due to adverse headwinds."

The lecturer had added that the requirements of the "chosen instrument" in this country were so different from those of other actual and potential operators that no metal aircraft built for this country was sold to another operator.

Those aircraft, said Group-Capt. Williamson, were operated by Imperial Airways; and Sir Frederick had pointed out that when an unsubsidised competitor—British Airways—had entered the field of operation it had turned to the United States to buy the faster aircraft which its conception of efficient air transport had required.

With regard to Mr. Davenport's point that increased speed meant increased cost, Group-Captain Williamson agreed that that was so over a particular distance. But over all there was bound to be economy in flying time; and they knew from long experience that less flying hours meant ultimately less expenditure.

Who wanted slow aircraft? Not the pilots, who found both comfort and safety in speed; not the passengers, to whom speed was comfort and might be a matter of life or death or urgent and important business appointments; not the operators, who had already experienced the loss of passengers to smaller and faster aircraft; and not the manufacturer of aircraft, who, if comfort were the sole criterion, would lose orders to every other aircraft-building country in the world.

Therefore, he concluded, a vote for slow aircraft was a vote against national prosperity.

Lieut.-Colonel W. E. BRISTOW (Fellow): Summing up in support of comfort, he said their feelings had been harassed, as some of the speakers had intended them to be harassed, by putting forward passionately a mass of inaccurate detail which had no bearing on the subject under discussion. One speaker had said that a comfortable seat marked the doom of aircraft design in this country, and the British Empire would become a back number.

The debate had really concluded before it had started; astonishingly, Major Mayo had started off by summing up for those who were urging comfort, for he had said that no requirements of speed should interfere with comfort requirements. That, said Col. Bristow, is the case for comfort.

Another remark that was made by those who wished to be uncomfortable was that comfort requirements had been static for some time past, whereas the world was out for more and more speed. But that was not true. When the steamship was invented, its object was to take passengers from place to place as quickly as possible; and the same

was true of aircraft. But in steamships, as evidenced by our last pre-war vessel, the "Queen Mary," they had witnessed an ever-increasing scale of comfort with increased performance. It was of no use discussing the design of aircraft and the relative speeds of aircraft to-day as compared with those of 1920, any more than it was worth while discussing the speeds of steamships of fifty years ago. When recalling the reference by the Air Vice-Marshal to the interest of passengers in a British aircraft when it had passed another aircraft in the 1920s, it must be remembered that the British aircraft provided a high standard of comfort and had a speed 25, 30 or 40 per cent. higher than the other. Then Professor Hill, in his opening remarks, had said that for a 10 per cent. increase of comfort there would be a loss of only about 1 per cent. in speed. That had not been contradicted and, coming from Professor Hill, one attached very great importance to it.

The exhaustive series of graphs, diagrams and schedules relating to the operation of commercial aircraft had been most interesting; but, with all respect to those who had taken so much trouble to compile them, they really did not affect the case at all, for the public would settle the question, just as they had in the spheres of motor cars and steamships; and compromise was inevitable. The degree of comfort to be provided in aircraft would be settled in each case according to the lengths of the routes to be covered, according to whether they were trans-ocean routes or overland routes, the distances between aerodromes, and so on. But it must not be forgotten that the public were becoming increasingly luxury-minded; the mighty success of the increasingly large steamships, up to the "Normandie" and the "Queen Mary," showed that the world demand was for extreme comfort.

It was wrong to introduce the word "luxury" in the debate, for it was not in the title. But the public were demanding more comfort. They paid twice as much for a first-class ticket as for a third-class ticket in order to obtain more comfort in only a short railway journey. Again, most of the claims made in respect of motor car design had been in respect of increased comfort as well as increased performance; designers provided from year to year more space, more comfortable seats, more room for baggage.

One could be certain that the designers of aircraft would be as clever as the designers of motor cars and ships. As showing that comfort and speed were not opposed in the exaggerated manner that had been suggested during the debate, one had only to recall that the most luxurious ship afloat up to 1936 had achieved the world's record for speed during its first crossing of the Atlantic.

He asked that, in recording their votes, those present at the meeting would preserve open minds and would not be inflamed by the exaggerated remarks of some of the speakers.

The voting resulted as follows:—

For the motion ..	71
Against	29

CORRESPONDENCE

MANIFESTATIONS OF ST. ELMO'S FIRE IN A TROPICAL STORM.

To the Editor.

May, 1945.

Dear Sir,—The following record may be of interest to many members of the Society:—

Conditions Prevailing.

On the night of 31st March, 1945, it was decided to fly non-stop from Pretoria to Kisumu, on Lake Victoria, Nyanza, a distance of some 1,850 statute miles. The route forecast for the hours of flight indicated a certain amount of high and medium cloud, but no serious meteorological hazards, and the aircraft was airborne at 20.00 hrs. G.M.T. Shortly before 01.00 G.M.T. on the 1st April, a long dark line of cloud, frequently illuminated by flashes of lightning, was discernable lying immediately across the track. An alteration of course was made to the east in an attempt to fly around the band of storms. After 100 miles on this track, it became obvious that the line of storms was in no manner abating, so it was decided to alter course again, and attempt to get through to the west. At this time the pressure altitude was 14,500 ft. above the M.S.L. datum at Pretoria and the outside air temperature was plus 8°C. As far as could be judged the vertical extent of the Cu. on this portion of the line was in the order of 25-30,000 ft., so it was impracticable to climb out above it, and it was equally impracticable to attempt to go underneath the cloud, as mountains up to 11,000 ft. rise out of a plain of a mean altitude of 4,000 ft. The new track to the west followed a line from the northern tip of Lake Nyasa to the southern tip of Lake Tanganyika. After flying some time on this track, it appeared that the best chance of getting through was midway between these two points as the cloud appeared lower and more broken, and lightning was less frequent. Course was set accordingly, and the belt of cloud entered.

The Storm Itself.

At first only broken small Cu. was met with, but turbulence increased rapidly, and became most severe in the region almost clear of medium cloud between the main stormbelt and the broken Cu. just mentioned. The anvil from the main Cu-Nimb. now obscured the sky, and the absolute blackness was frequently illuminated by the constant lightning which threw the nearer clouds into relief against the background of the main storm. A portion dead ahead appeared to be free of lightning and it was decided to carry straight on. Just before the aircraft entered the cloud a blue corona-like discharge was visible around the periphery of the airscrews. As soon as the aircraft was in the cloud, turbulence increased slightly and the air temperature dropped to plus 3°C.

Immediately the corona discharge turned into a brush discharge, pointing forward, from all the protruding portions of the aircraft, the airscrews and spinners being affected particularly. This discharge was very inconstant, changing from a scarcely visible bluish ring around the airscrews to a brilliant display from every portion of the aircraft projecting forward and reaching a length of a foot or more. Then the discharge ceased altogether, and turbulence died down. A rapid rise was noticed on the altimeter, and also on the air speed indicator. A nearby flash of lightning illuminated the whole surrounding cloud, and the St. Elmo's Fire reappeared immediately, only this time in much greater intensity. The entire leading edge of the wing gave out a flat curtain of blue discharge, and the discharge from the engine nascelles and airscrews projected out forward as far as the front cockpit, tattered

bits of the discharge breaking away and "dissolving." Even projecting rivets inside the perspex observation dome and the windshield de-icing pipes gave rise to pennant-like discharges, and the actual nose of the aircraft seemed to be attached to a curling rope of blue flame stretching out ahead into the night. This all lasted perhaps five seconds, the phenomena rising in intensity, then suddenly the aircraft was struck by a direct flash. The noise gave the impression of a terrific explosion and the aircraft seemed momentarily filled with flame and blinding brilliance. It was several seconds before control was regained, and our eyes had recovered, and by that time all the signs of St. Elmo's Fire had disappeared. One further small discharge was visible comparable with the first corona manifestation.

Survey of the Damage Done.

All radio and radar equipment was completely unserviceable, several electrical circuits had been put out of action, in particular those with long unshielded leads running the length of the aircraft. The flash appeared to have entered the aircraft on the starboard side of the nose and the tip of the starboard wing, where rivets and edges of the skin were pock-marked with small "spot-welds" from the passage of the flash. Several of these marks penetrated deep into the skin, and appeared to be flash-overs from poorly riveted (electrically) or poorly bonded portions of the structure. The de-icing device on this aircraft consists of a woven metal wick attached to the leading edges, and this was ruptured along its entire length, and the strands of metal blown back against the surface of the wing. They were too damaged by the slipstream to show what type of fusing had taken place. The leading edges of the wing were loosened on their rivets, and numerous other small structural faults were found, but none very serious. Two very remarkable points were, however, firstly that the compasses were only slightly affected, and secondly the Mk. IXa Bubble Sextant hanging in the observation dome had all its electrical circuits fused together in a solid mass.

Further Remarks.

It is considered that the aircraft, an Avro York 4-engined transport, acquitted itself remarkably well considering the severe strains to which it was subjected.

It would appear that merely earthing the radio equipment in an aircraft does not afford it much protection in the case of a severe strike by lightning.

The storm belt encountered would appear to have been associated with an inter-tropical front which had increased activity during the hours of darkness.

The passengers on this occasion were Field Marshal the Rt. Hon. J. C. Smuts and his Staff, on the first stage of their journey to the San Francisco Conference.

Yours faithfully,

T. G. E. COCKBAIN, A.R.Ae.S., F.R.Met.S.

To the Editor.

25/4/45.

Dear Sir,—I am in entire agreement with Major Green's correction of the very unrealistic $600 per pound. The latter overlooks two important factors:—

(*a*) That the carriage of an extra passenger normally involves an important addition to the empty weight of the aircraft.

(*b*) That even if one extra passenger is carried in an aircraft, he still has to be advertised, arranged and catered for, looked after, etc., and that the cost of such services is extremely important in the U.S.A.

Even when these factors are accounted for and whatever assumptions are used, the potential value of weight saving is always very high.

As there is a danger that people may be tempted to save this valuable weight by sacrificing even more valuable aerodynamic or power plant efficiency, a warning of possible false economies will be given by

illustrating how much these other factors are worth.

They are so important that Major Green's allowance for extra drag is insufficient if the fuselage size has to be increased very appreciably to take additional passengers. However, I will first adjust my assumptions to agree with those of Major Green.

What is the value of one pound of weight saved?

Major Green's assumptions are equivalent to a direct operating cost of 0.8 pence per seat-mile, which is of the right order for present operation of efficient aircraft of the class considered. The airframe life is taken as 15,000 flying hours at an average point to point speed of 200 m.p.h.

Each pound saved is equivalent to an extra one four-hundredth of a seat with a life of three million miles, a saving of

$(3{,}000{,}000 \times 0.8) / 400 \times 0.8$ pence per lb.
= £25 per lb. over the life of the airframe.

I regard this as a better measure of the direct effect of weight saving. It is not always true at present that weight saving necessarily means extra manufacturing costs and in any case the operator and manufacturer will have to decide how the saving is divided between themselves and the passengers when fixing the price of aircraft and spares.

What is the value of aerodynamic and power plant efficiency?

I assume that Major Green is thinking in terms of conventional petrol-engined aircraft with characteristics similar to the following (corrected to round figures):—

Total cruising power—1/20 b.h.p. per lb. of aircraft.
Petrol consumption 2/5 lb. per b.h.p. per hour.
Engine or airframe price—£1 per lb.
Fuel price—3d. per lb.
Price of one propeller—15 per cent. of an engine.
Engine and propeller life—6,000 hours.
Weight of engines—20 per cent. of aircraft weight.
Weight of airframe—25 per cent. of aircraft weight.
Average flying distance—1,000 miles.
Average fuel reserve—50 per cent.

From this additional data, it may be shown (as in the Appendix to this letter) that even when it is assumed that the engine size is already fixed by take-off or similar limitations:—

(i) 15 per cent. of the price of an engine is saved by each 1 per cent. reduction in fuel consumption.
(ii) More than 30 per cent. of the price of an airframe is saved by each 1 per cent. reduction in aerodynamic drag.
(iii) More than the complete price of a propeller is saved by every 1 per cent. overall increase in its efficiency.

Moreover, if the engine size is decided by its cruising power (as will become increasingly evident for higher speeds and altitudes), the savings are increased to

More than 50 per cent. of the airframe price per 1 per cent. drag reduction.
More than 167 per cent. of the propeller price per 1 per cent. overall increase in efficiency.

(The effect of fuel consumption is unchanged at 15 per cent.)

It will be appreciated that such estimates can only give the order of saving in the long run, since it might be difficult to take full advantage of small savings in an actual case. The exact values depend considerably on the circumstances, but the above typical values are sufficient to show that it is essential to take account of *all* the factors contributing to the efficiency of an aircraft. Just as a somewhat surprising figure of so many £ per lb. should not be translated as meaning that everything must be subordinated to attaining the lightest possible empty weight, so, in turn, an ever more surprising figure of the saving from every small increase in aerodynamic or power plant efficiency should not

be interpreted by subordinating weight saving.

Taking a specific illustration from the above example, if the 1 per cent. reduction in engine fuel consumption can be attained only at the expense of $1\frac{1}{2}$ per cent. increase in the engine weight, no saving will result. Conversely a $1\frac{1}{2}$ per cent. reduction in engine weight is very worth while, but not if it results in an increase in fuel consumption of more than 1 per cent. (so long as it still uses the same fuel). I agree with Major Green that the largest bonuses from pure weight reduction is mostly obtainable from the equipment which is partly out of the control of the aircraft or power plant manufacturer.

All these factors do add up to show one extremely important conclusion. The simultaneous improvements in structure, power, plant, equipment, aerodynamic and other aspects of efficiency (compromised where necessary) have a bearing on the future economy, safety and usefulness of air transport which is out of all proportion to the cost of the aircraft employed.

Yours faithfully,

R. F. CREASEY.

APPENDIX

For simplicity, this analysis will neglect any minor factors.

Let W = aircraft weight in lb.

Considering the effect of a 1 per cent. change in each case, 1 per cent. less fuel is carried and burnt in maintaining the same speed.

∴Fuel weight saved per hour

$$= \frac{1}{100} \times \frac{2}{5} \times \frac{W}{20} = .0002W \text{ lb.}$$

Fuel cost saved per hour

$$= .0006W \text{ pence}$$

Weight saved on an average trip

$$= .0002 \times \frac{1000}{200} \times 1.5 = .0015W \text{ lb.}$$

(i) Saving over the life of the engines

$$= £\left\{\frac{.0006 \times 6000}{240} + .0015 \times 25 \times \frac{6000}{15000}\right\} W$$

$= £.03$ W, which is 15 per cent. of the price of the engines.

(ii) Saving over the life of an airframe

$$= £.03 \text{ W} \times \frac{15000}{6000}$$

$= £.075$ W, which is 30 per cent. of the price of the airframe. In addition to this, there is the smaller wear and tear on the engines due to the smaller cruising output.

(iii) Saving over the life of the propeller $= £.03$ W (plus saving in engine wear and tear) which compares with £.03 W for the price of the propeller.

If the size of the engines is fixed by cruising output, the weight of engine can be reduced by .002 W lb. in the latter two cases.

This increases the saving in these two cases by $66\frac{2}{3}$ per cent., in addition to the saving in depreciation, ground service and overhaul with the smaller engines.

To the Editor.

Sir,—I have read with interest the discussion* on the training required for those engaged in civil flying, and was extremely disappointed to find that not only was the ability of our Royal Air Force aircrew grossly under-estimated, but also that those who protested against such under-estimation did so in such mild statements that their protests may have been overlooked. I would, therefore, like to add a few comments on the discussion, even though I am somewhat belated.

I am in the fortunate position, in viewing this subject, of having spent many years of active participation in civil aviation as a member of the greatest British air line; and to have coupled this experience with an active part in operations and in the control of operations throughout the Bomber offensive with its developments of midern equipment. I therefore know intimately and am a close personal friend of many air line pilots and at the same time I am in day to day touch with the flying crews of Bomber Command. I hope, therefore, that I can claim to view the problem with the knowledge of

* Journal, February, 1945.

all its aspects and without bias. In the previous discussion the statement was made that pilots of the Royal Air Force would take one year to be adequately converted to fly civil aircraft, whilst I would point out that there are many, particularly in Bomber Command, who already possess experience and ability of the standard required for civil flying. They would, of course, require some conversion training, but to talk in terms of a year is quite fantastic. If that is the scale of training required—well, then, it is certain that existing experienced pilots would take at least a year to bring themselves up to date with the modern equipment to which they have not had access due to security regulations during the war. I hope, however, that my civil friends will not take this wild statement seriously. I do not really think they would require more than a short course to modernise their outlook on the new devices. My point is simply that heavy bomber crews of considerable experience do not, in fact, require such an extremely long period of training as has been suggested. Quite apart from anything else, a year's training for a heavy pilot would cost at a rough estimate about £5,000 per head.

Whilst I do not suggest that pilots who have been flying single-engined and twin-engined aircraft are likely to find posts in civil aviation, I do wish to stress, particularly to those in civil flying, that we have a reserve of talent in the Royal Air Force which is of tremendous value to civil aviation. We must not allow any " dog in the manger " attitude to deprive us of the services of these excellent men. This is not merely a matter of gratitude for the work which they have done, but is just simple practical business sense. In particular, the crews in Bomber Command have had to tackle a job far more difficult than anything ever demanded in civil flying. They have experience of heavy four-engined aircraft, flying to wing loads far exceeding any civil practice, at night, often in adverse weather conditions with black-out restrictions on the ground and in the aircraft, coupled with the ever present danger of enemy fighters and other enemy defences and subject at all times to enemy radio and radar countermeasures. Such experience cannot and must not be wasted. Moreover, it must not artificially be held down or belittled. The civil pilots will, I know, welcome the young serving types; I hope that all others in civil aviation will do likewise.

Air Vice-Marshal D. C. T. BENNETT,
Royal Air Force, Huntingdon.
27th March, 1945.

REVIEW

Flight Handbook. Flight Publishing Co. Ltd., London. 1944. 7s. 6d. net.

This is the fourth edition of one of the most useful handbooks published. It has now, indeed, become a standard work on aeronautical theory and practice, and is a book which should have a wide reading public, quite apart from those actively engaged in aviation. Written in the simplest terms, with excellent diagrams and photographs, it gives a clear insight into the why and wherefore of flying.

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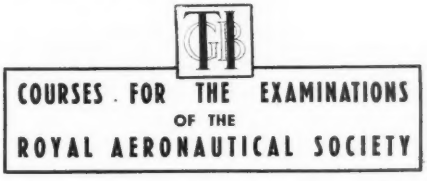

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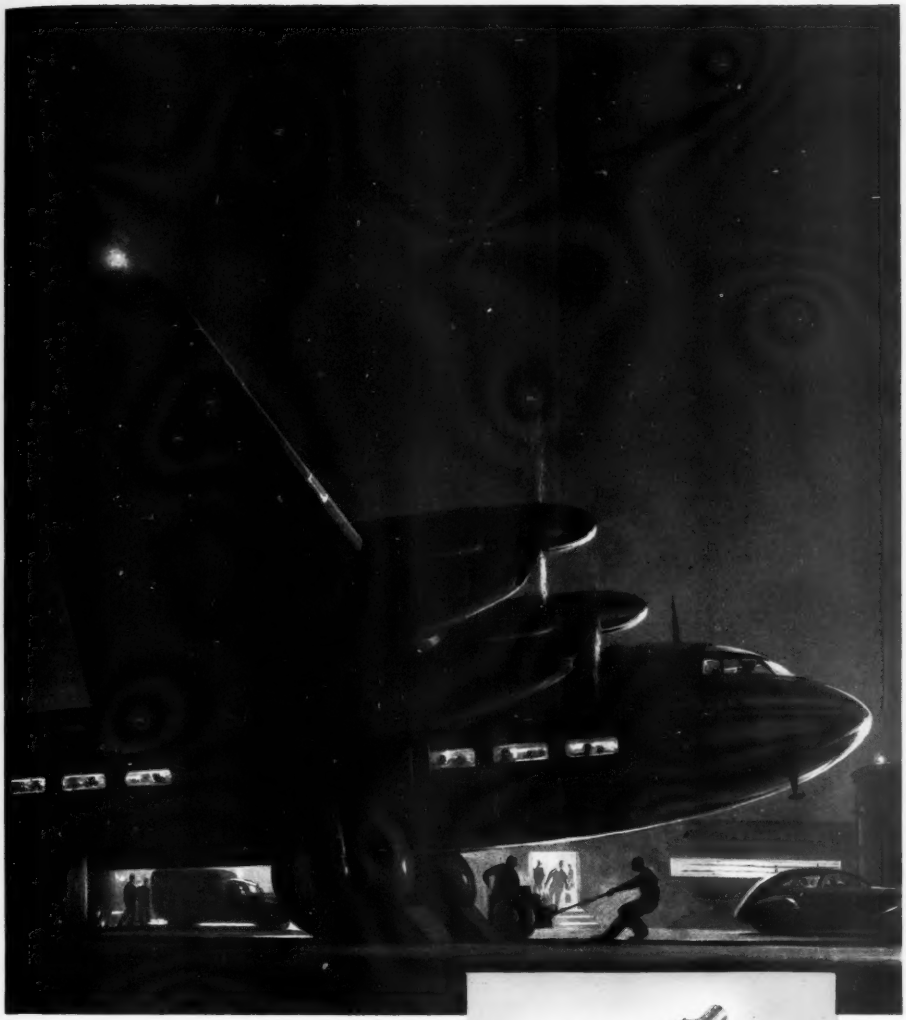

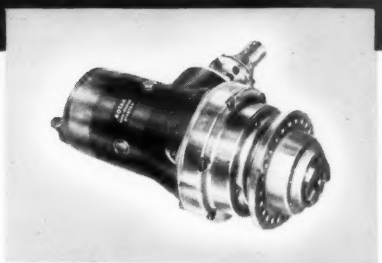

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